ASSESSMENT OF CHRISTINA LAKE WATER QUALITY DATA 1972 - 1990

BC Environment

91-06866/

ASSESSMENT OF CHRISTINA LAKE WATER QUALITY DATA 1972 - 1990

J.R. Ellis*
S.P. Wilkins*
J.E. Bryan

Environmental Protection
B.C. Environment
3547 Skaha Lake Road
Penticton, B.C.
V2A 7K2

*Sigma Engineering Ltd.
800 - 1176 West Georgia Street
Vancouver, B.C.
V6E 4A2

JUNE 1991

Canadian Cataloguing in Publication Data
Ellis, J. R. (Joanne Ruth), 1963-
Assessment of Christina Lake water quality data 1972-1990

ISBN 0-7726-1380-X

1. Water quality - British Columbia - Christina Lake (Kootenay Boundary) 2. Christina Lake (Kootenay Boundary, B.C.) I. Wilkins, S. P. II. Bryan, J.E. III. British Columbia. Environment. III. Title.

TD227.B7E44 1991 363.73'942'0971162 C91-092230-6

PREFACE

This report was prepared to summarize existing information necessary for setting water quality objectives in Christina Lake and its tributaries. Maintaining good water quality in British Columbia is a goal of both the Environmental Protection and Water Management Programs of B.C. Environment. Based on the findings of this report, additional samples and observations will be obtained so that technically defensible objectives can be set for Christina Lake and its important tributary streams.

EXECUTIVE SUMMARY

Citizens living near Christina Lake have expressed concern about perceived water quality changes in Christina Lake. They noticed changes in a number of aesthetic aspects of water quality such as detritus on beaches and oily films on the lake surface. As a result, they requested that B.C. Environment review the quantitative data on water quality in Christina Lake. This report documents the results.

Two additional studies were also commissioned at the same time by the Ministry of Municipal Affairs at the request of concerned Christina Lake citizens. One of these studies investigated the feasibility of the installation of a sewer system while the other studied the possibility of incorporation of the area.

This report describes the quantitative measures of water quality made in Christina Lake over the last 18 years. These measures show Christina Lake to have water of quite high quality. The nutrient content of the lake is low. Nutrients are required to produce phytoplankton (tiny aquatic plants) which in turn support zooplankton (very small aquatic animals), important food for fish. Lakes with low nutrient content generally contain low densities of phytoplankton and have good water clarity, making them desirable for recreational activities such as swimming and boating.

The data analysis in this report found the water quality of Christina Lake to have remained relatively consistent since the 1970's, when data was first collected. The analysis found no trends to indicate deteriorating water quality. Bacteriological quality of the water was good, and well within the Canadian Guidelines for Recreational Water Quality (1983). The study found that at different times, either phosphorus or nitrogen can theoretically limit biological growth in Christina Lake, however, phosphorus limitation is probably the more usual case. Therefore increased nutrient loadings from any source, such as agriculture, domestic sewage, or forestry activities could increase phytoplankton growth and decrease water quality.

The water quality monitoring data and recommendations contained in this report provided the background for a program to monitor water quality. Based on the results of this monitoring, water quality objectives will be set for Christina Lake and its major tributaries. These objectives will assist in management decisions necessary to maintain the quality of Christina Lake in its present state.

ASSESSMENT OF CHRISTINA LAKE WATER QUALITY DATA 1972 - 1990

Preface			iii
Executive Summary			iv
Table of Contents			vi
List of Tables			viii
List of Figures			ix
Acknowledgements			x
Technical Abstract			xi
1.	INTRODUCTION AND BACKGROUND		1
	1.1	Previous Studies	1
	1.2	Current Water Quality Issues/Problem Areas	2
2.	BASIN DESCRIPTION AND LAND USE		2
	2.1	Physiography	2
	2.2	Climate	3
	2.3	Population and Settlement	6
	2.4	Forestry	6
	2.5	Mining	9
	2.6	Agriculture	10
3.	HYDROLOGY AND PHYSICAL LIMNOLOGY		10
	3.1	Hydrology of Tributaries	10
	3.2	Christina Creek Hydrology	11
	3.3	Physical Limnology	15
4.	WATER USES		17
	4.1	Water Licences	17
	4.2	Domestic Water Supply	18
	4.3	Recreational Use	18
5.	WASTE DISCHARGES		18
	5.1	Point Sources	18
	5.2	Non-Point Sources	20
6.	LAKE PRODUCTIVITY		20
	6.1	Chlorophyll *a*	21
	6.2	Phytoplankton	21
	6.3	Zooplankton	22
	6.4	Eurasian Watermilfoil	23
	6.5	Fish	23

7. WATER QUALITY 26
7.1 Data Sources 26
7.2 Nutrients 26
7.3 Metals, Hardness 35
7.4 pH, Alkalinity 35
7.5 Turbidity, Solids, Secchi Disk Depths 38
7.6 Dissolved Oxygen, Temperature and Conductivity 38
7.7 Bacteriological Quality 42
7.8 Tributary Water Quality Sampling 44
8. LAKE TROPHIC STATUS AND CARRYING CAPACITY 45
9. REVIEW OF CURRENT SAMPLING PROGRAM 47
10. DRAFT TERMS OF REFERENCE FOR MONITORING 47
10.1 Short-term Monitoring Program 47
10.2 Long-Term Monitoring Program 49
11. CONCLUSIONS 50
REFERENCES 52
APPENDICES
A. Tables and Figures
B. Water Licence Data
C. Eurasian Watermilfoil Data

LIST OF TABLES

Report Tables

1	Long term climate data, Grand Forks
2	Forestry data, area by age class
3	Christina Creek at the outlet of Christina Lake, level data
4	Spring Total Nitrogen to Total Phosphorus Ratios
5	Christina Lake maximum metal concentrations
6	Christina Lake extinction depth, turbidity and solids
7	Comparison of dissolved oxygen values

Appendix A Tables

A1	Farron Snow Course data
A2	Sutherland Creek near Fife, discharge data
A3	Moody Creek near Christina Lake, discharge data
A4	Big Sheep Creek near Rossland (WSC, 1989)
A5	Christina Creek at the outlet of Christina Lake, discharge data
A6	Christina Lake and tributaries, water licence data
A7	Chlorophyll a concentrations in Christina Lake
A8	Christina Lake phytoplankton summary
A9	Christina Lake zooplankton summary
A10	Total phosphorus concentrations
A11	Total dissolved phosphorus concentrations
A12	Ortho dissolved phosphorus
A13	Total Kjeldahl Nitrogen - Station 0200078
A14	Total Kjeldahl Nitrogen - Station 0200520
A15	Christina Lake pH and alkalinity station averages
A16	Ministry of Health beach sampling fecal coliform data
A17	Christina Lake coliform data from SEAM
A18	Sutherland Creek sampling results
A19	Parson and Treadmill creeks, Ministry of Health sampling results

LIST OF FIGURES

Report Figures

1	Christina Lake watershed
2	Christina Creek estimated outlet discharges
3	Christina Lake bathymetric map
4	Christina Lake recreational areas
5	Christina Lake water quality sampling sites
6	Spring total and dissolved phosphorus concentrations
7	Stratified lake total dissolved phosphorus
8	Stratified lake total phosphorus
9	Organic nitrogen concentration (Station 0200078)
10	Organic nitrogen concentration (Station 0200520)
11	1981 Christina Lake temperature and dissolved oxygen profiles
12	1988 Christina Lake temperature and dissolved oxygen profiles

Appendix A Figures

A1	Proposed logging activity
A2	1980 Christina Lake temperature and dissolved oxygen profiles
A3	1986 Christina Lake temperature and dissolved oxygen profiles
A4	1990 Christina Lake temperature and dissolved oxygen profiles
A5	Christina Lake conductivity profiles

ACKNOWLEDGEMENTS

This report was prepared under a B.C. Environment contract to Sigma Engineering Ltd. The study team consisted of S.P. Wilkins, Project Manager, and J.R. Ellis, Project Engineer.

J.E. Bryan, Head of Environmental Assessment with B.C. Environment, drafted and monitored the contract, provided data, and edited the report. Dr. R.N. Nordin of B.C. Environment provided ongoing assistance and advice throughout the report preparation as well as a thorough review of the draft report.

A number of individuals provided assistance in the form of data, reports, comments and advice including Bruce Bourdon of the Kootenay Boundary Regional District; the Christina Lake Citizen's Study Group; Lorraine Thompson of Central Kootenay Health Unit in Grand Forks; David Kilshaw, David Toews, and Doug Thorpe of the Ministry of Forests; and Neil Banera and Nellie Peppin of B.C. Environment. Their help is greatly appreciated.

TECHNICAL ABSTRACT

Christina Lake water quality data collected by B.C. Environment between 1972 and 1990 were summarized and evaluated. The current status of the lake water quality was assessed and data were evaluated to determine if there were any trends or deterioration in water quality.

Current overall water quality in Christina Lake is very good and has remained relatively unchanged since the water quality and productivity study done in 1979 by the Ministry of Environment (Crozier 1979). Nutrient levels in the lake were low for the 1980 - 1990 sampling period, with total phosphorus concentrations averaging 0.008 mg/L in spring and 0.006 mg/L in summer surface samples; and total nitrogen concentrations averaging 0.09 and 0.10 mg/L for the spring and summer samples respectively. Christina Lake remains classified as an oligotrophic (low productivity) lake. This is due to the low nutrient levels and low productivity as indicated by chlorophyll *a* concentrations.

Dissolved oxygen concentrations remain undepleted and suitable for salmonid growth even in the late summer hypolimnion. Water clarity is very good, with 90 % of recorded Secchi Disk extinction depths greater than 7.4 metres.

One change that has occurred in the lake since the 1979 MOE study (Crozier 1979) has been the introduction and spread of Eurasian watermilfoil, which was first documented in 1986. This is not an indication of a change in water quality, but rather the introduction of the species from another lake.

The bacteriological water quality of Christina Lake is also good, with all beach samples taken by the Ministry of Health since 1986 being within the Guidelines for Canadian Recreational Water Quality (1983). Metal concentrations measured by B.C. Environment were below the maximum allowable criteria for protection of freshwater aquatic life (Pommen 1989) and within the guidelines recommended for drinking water in the Canadian Water Quality Guidelines (1989).

1. INTRODUCTION AND BACKGROUND

The purpose of this report is to summarize water quality information for Christina Lake, and to assess the current status and any trends in lake water quality. The report will also serve as part of the technical information used by the B.C. Environment Water Management Branch to set water quality objectives for the lake.

1.1 Previous Studies

Due to the high recreational value of Christina Lake, there is a long standing interest in monitoring and maintaining good lake water quality. Previous water sampling studies include:

Ministry of Health Sanitary Survey conducted in 1967 - as referenced in the Kootenay Boundary 1975 report. This study involved sampling some bacteriological parameters.

Ministry of Health 1970 Survey - as referenced in the Kootenay Boundary (1975) report. Eleven sites were sampled for total and fecal coliforms, nutrients and Secchi disk depth.

Ministry of Environment Report on Christina Lake Water Quality and Primary Productivity (Crozier 1979) - Water quality data collected over three lake stations in the 1970's were analyzed. Primary productivity and lake carrying capacity were also discussed.

Ministry of Health Water Quality Study (Philion, 1981) - Summarizes bacteriological and chemical water quality analysis on samples collected between May and October of 1978. Biweekly samples were collected from points along the east shore of Christina Lake ending at the provincial park beach. Although 18 sample sites were used, not all were sampled on every occasion.

Miscellaneous spot water quality samples have been collected by Fish and Wildlife Branch, B.C. Environment in conjunction with various fisheries surveys.

In addition to the water sampling studies, a recent study looking at water supply and wastewater disposal at Christina Lake is being completed by Kerr Wood Leidal (1991).

1.2 Current Water Quality Issues/Problem Areas

Local residents are concerned that the water quality of Christina Lake has deteriorated over the last decade. A major area of concern to local residents is seepage into the lake of sewage from septic systems. A recent study and survey by Kerr Wood Leidal (1991) found many septic systems to be inadequately maintained. In addition, a number of systems are aging, constructed in soils of inadequate depth over bedrock, or are located closer to the lake than current regulations allow. The input of sewage from campground septic systems is also thought to be a problem due to the concentrated use of these facilities over the summer months. Another concern is the possible input of nutrients from Sutherland Creek. Agriculture adjacent to the creek could be a source of nutrients, and in the past (Crozier 1979) the creek has been found to have fairly high phosphorus and nitrogen concentrations. Some residents have also expressed concerns about reported increased weed growth, algae blooms and water surface films. The residents are concerned that the water quality of Christina Lake may be deteriorating as a result of the increased development and the recreational activities adjacent to the lake in the summer.

2. BASIN DESCRIPTION AND LAND USE

2.1 Physiography

Christina Lake lies within the Monashee Mountain Range of the Columbia Mountains physiographic province. The lake is flanked by the Christina and Rossland ranges, which consist primarily of sedimentary and metamorphic complexes. The local rock types are late Paleozoic volcanic complexes and early Paleozoic heavily metamorphosed rocks such as gneisses, derived from sedimentary rocks (Holland, 1976), with a minor north-south fault along the Christina Lake basin.

The region was heavily glaciated until the Pleistocene (10,000 years B.P.) with a steady retreat of the Cordilleran Glacier Complex from its maximum extent over most of British Columbia 20,000 years B.P. Small cirque glaciers eroded the peaks and large valley glaciers occupied the major valleys until approximately 10,000 years before present. Local relief within the Christina Lake catchment is approximately 1500 metres, with peaks over 2100 metres along the northern boundary of the basin and the lake at an elevation of 453 metres above sea level. Large amounts of morainic, glaciofluvial and glaciolacustrine sediments fill the valley bottoms, and glacially derived sediments form the predominant surficial geological landforms. Detailed soils maps of the immediate lake shore area were prepared to assess development suitability (Regional District of Kootenay Boundary, 1975)

Christina Lake is part of the Columbia River drainage, draining south through Christina Creek and the Kettle River to flow into Roosevelt Reservoir on the Columbia River in Washington state. The drainage basin area of the lake above the outlet, as shown on Figure 1, is 492 km^2, and the surface area of the lake is 25.1 x 10^6 m^2.

2.2 Climate

The climate of the Christina Lake area can be typified by its location in the Interior Cedar-Hemlock biogeoclimatic zone. This zone is typified by cool snowy winters and warm dry to moderately moist summers.

The closest climate station to the Christina Lake basin is located at Grand Forks, where Environment Canada has been recording temperature and precipitation since 1940. The climatic normals for the period 1951-1980, which represent a long term average, are given in Table 1 (Environment Canada, n.d.). The mean annual daily temperature is 7.3 ^{o} C., with a mean annual daily minimum temperature of 0.9 ^{o} C and a mean annual daily maximum temperature of 13.7 ^{o} C. The long term average total precipitation for the period of record is 447 mm, with 323.7 mm rainfall and 123.4 mm (water equivalent) of snowfall.

The snowfall data for Grand Forks will not be very representative of much of the Christina Lake basin, which primarily lies at higher

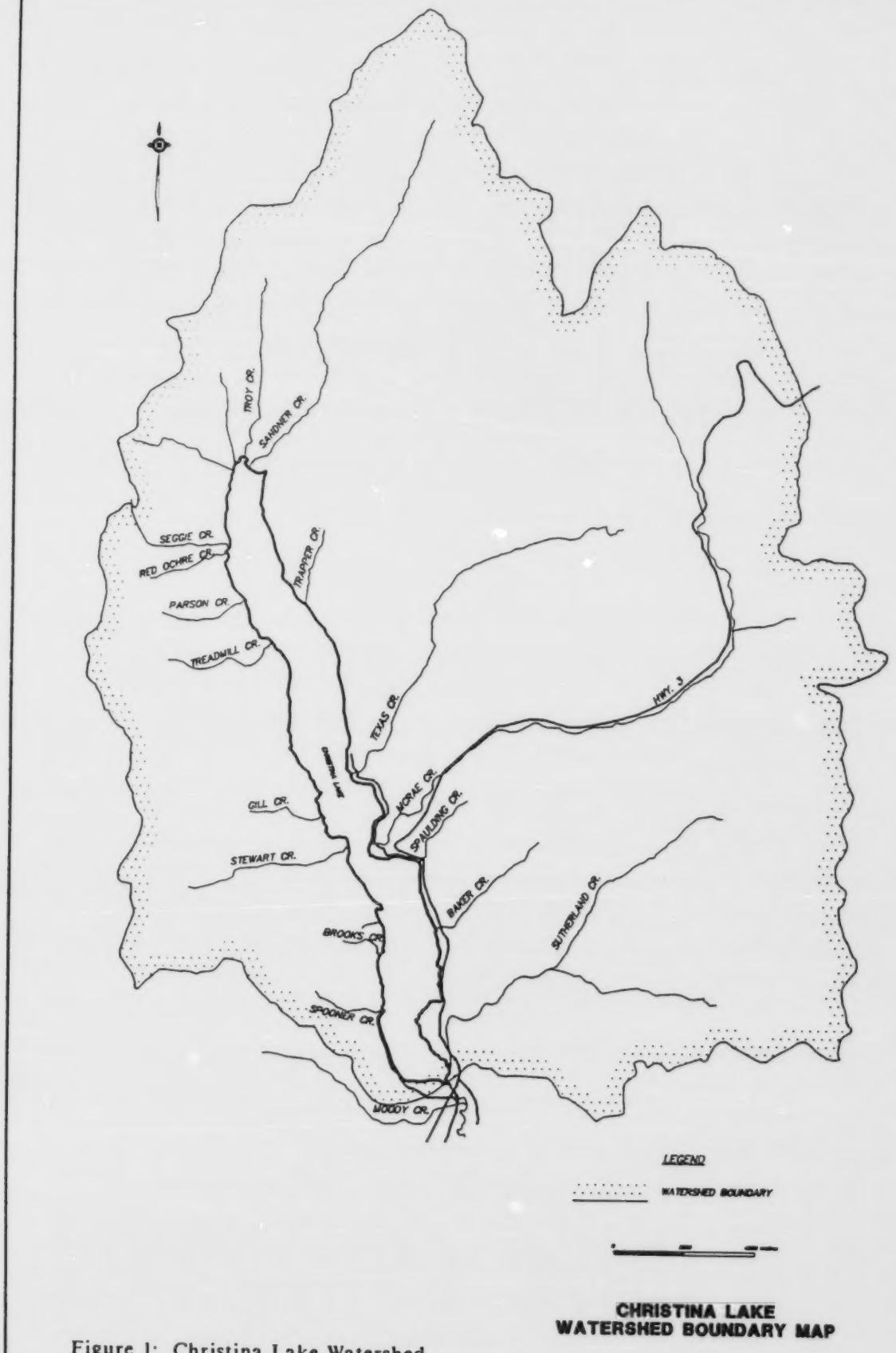


Figure 1: Christina Lake Watershed

BRITISH COLUMBIA/COLOMBIE-BRITANNIQUE

	JAN JAN	FEB FÉV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEP SEPT	OCT OCT	NOV NOV	DEC DÉC	YEAR ANNÉE	CODE CODE	
GRAND FORKS															
49° 2'N 118° 28'W 532 m															
Daily Maximum Temperature	-2.2	2.9	8.3	15.0	20.2	23.9	28.8	27.8	22.5	13.8	4.3	-0.6	13.7	1	Température Maximale Quotidienne
Daily Minimum Temperature	-10.0	-6.3	-3.3	0.7	5.0	8.5	10.3	9.7	5.7	0.8	-3.4	-7.2	0.9	1	Température Minimale Quotidienne
Daily Temperature	-6.1	-1.7	2.5	7.9	12.6	16.3	19.6	18.8	14.1	7.3	0.4	-3.9	7.3	1	Température Quotidienne
Standard Deviation, Daily Temperature	3.3	2.4	1.8	1.2	1.6	1.5	1.2	1.6	1.6	1.0	2.0	2.6	0.7	1	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	16.1	19.4	21.7	31.7	36.1	36.1	42.2	39.4	36.7	30.0	18.9	25.0	42.2		Température Maximale Extrême
Years of Record	39	40	39	40	40	40	40	40	40	40	38	40			Années de Relèves
Extreme Minimum Temperature	-36.9	-35.0	-22.8	-8.3	-8.3	-1.7	1.1	0.0	-6.1	-11.1	-23.3	-37.8	-36.9		Température Minimale Extrême
Years of Record	39	40	40	40	39	38	39	39	40	40	40	40			Années de Relèves
Rainfall	10.5	15.1	19.5	26.6	44.1	45.6	26.0	39.6	25.8	28.3	27.6	15.0	323.7	1	Chutes de Pluie
Snowfall	41.2	19.0	7.3	0.6	0.0	0.0	0.0	0.0	0.0	0.7	15.0	39.6	123.4	1	Chutes de Neige
Total Precipitation	51.6	34.1	26.8	27.2	44.1	45.6	26.0	39.6	25.8	29.0	42.6	54.6	447.0	1	Précipitations Totales
Standard Deviation, Total Precipitation	16.7	18.5	12.6	16.0	21.6	23.1	17.0	29.0	17.4	19.3	21.5	19.4	59.9	1	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	14.7	17.0	16.0	21.8	31.2	41.4	47.8	38.4	24.4	27.4	22.6	15.7	47.8		Chute de Pluie Record en 24 heures
Years of Record	40	39	40	40	40	40	40	38	40	40	40	40			Années de Relèves
Greatest Snowfall in 24 hours	40.6	25.4	17.8	10.2	T	0.0	0.0	0.0	0.0	7.6	17.8	30.5	40.6		Chute de Neige Record en 24 heures
Years of Record	40	40	40	40	40	40	40	40	40	40	40	40			Années de Relèves
Greatest Precipitation in 24 hours	40.6	25.4	16.0	21.8	31.2	41.4	47.8	38.4	24.4	27.4	22.6	30.5	47.8		Précipitation Record en 24 heures
Years of Record	40	40	40	40	40	40	40	38	40	40	40	40			Années de Relèves
Days with Rain	3	5	7	8	11	10	6	8	8	8	8	5	87	1	Jours de Pluie
Days with Snow	11	5	2	*	0	0	0	0	0	*	4	9	31	1	Jours de Neige
Days with Precipitation	14	10	9	8	11	10	6	8	8	9	12	14	119	1	Jours de Précipitation
GRASMERE															
49° 6'N 115° 5'W 869 m															
Daily Maximum Temperature	-2.3	3.6	7.5	13.8	19.1	22.8	28.3	27.0	21.1	13.1	3.7	-0.2	13.1	8	Température Maximale Quotidienne
Daily Minimum Temperature	-9.2	-5.3	-3.6	0.2	4.4	7.7	10.3	9.6	5.2	0.5	-3.4	-6.4	0.8	8	Température Minimale Quotidienne
Daily Temperature	-5.7	-0.9	2.0	7.0	11.8	15.3	19.3	18.3	13.2	6.8	0.2	-3.3	7.0	8	Température Quotidienne
Standard Deviation, Daily Temperature	4.3	2.0	2.5	1.9	1.2	1.9	1.6	2.1	2.4	1.8	1.7	3.6	0.6	4	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	12.8	20.0	22.2	30.0	33.9	35.6	38.9	39.4	35.6	30.5	20.6	13.3	39.4		Température Maximale Extrême
Years of Record	19	19	18	18	18	19	19	19	19	18	19	18			Années de Relèves
Extreme Minimum Temperature	-36.0	-26.7	-23.9	-10.6	-6.1	-2.0	0.0	0.0	-6.7	-15.6	-25.6	-42.8	-42.8		Température Minimale Extrême
Years of Record	19	19	19	19	19	18	19	19	19	19	18	18			Années de Relèves
Rainfall	15.9	17.8	12.3	26.0	56.3	68.8	41.8	54.7	37.5	24.1	24.6	18.2	398.0	8	Chutes de Pluie
Snowfall	31.4	15.5	9.5	6.0	0.4	0.0	0.0	0.0	0.1	4.1	14.8	27.4	109.2	8	Chutes de Neige
Total Precipitation	43.3	29.9	21.3	29.8	56.7	68.8	41.8	54.7	37.4	28.0	38.4	43.6	493.7	8	Précipitations Totales
Standard Deviation, Total Precipitation	23.4	19.6	9.5	23.8	26.3	44.3	30.9	47.2	23.9	15.0	40.1	27.6	100.8	4	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	21.6	26.9	16.3	30.2	33.3	45.2	37.1	43.9	40.6	18.6	34.3	22.4	45.2		Chute de Pluie Record en 24 heures
Years of Record	18	17	19	18	17	18	17	19	19	17	17	17			Années de Relèves
Greatest Snowfall in 24 hours	26.7	16.5	17.8	43.2	5.1	0.0	T	0.0	3.8	17.8	15.2	27.9	43.2		Chute de Neige Record en 24 heures
Years of Record	18	17	19	18	19	19	19	19	19	18	17	17			Années de Relèves
Greatest Precipitation in 24 hours	26.7	26.9	16.3	43.2	33.3	45.2	37.1	43.9	40.6	18.6	34.3	27.9	45.2		Précipitation Record en 24 heures
Years of Record	17	17	19	18	17	18	17	19	19	17	17	17			Années de Relèves
Days with Rain	3	3	3	6	8	8	6	7	6	5	4	4	63	8	Jours de Pluie
Days with Snow	6	3	2	1	0	0	0	0	0	1	3	6	22	8	Jours de Neige
Days with Precipitation	9	6	5	6	8	8	6	7	6	5	7	9	82	8	Jours de Précipitation

Table 1: Long term climate data, Grand Forks (Environment Canada, n.d.)

elevations. The closest snow course station to the upper portions of the Christina basin is located just over the divide to the east, in the headwaters of the Lower Columbia River drainage basin above Trail (B.C. Ministry of Environment, 1980). The station name is Farron #1, and it is located at 1220 m. above sea level. The mean snowpack for April 1 is 338 mm (water equivalent) with a snowpack depth of 100 cm. (Table A1 in Appendix A). These data indicate that the precipitation in the upper portions of the Christina Lake basin may be significantly higher than that recorded at Grand Forks, and that a higher proportion of the precipitation will fall as snow.

2.3 Population and Settlement

The permanent population of the Christina Lake Community as of 1990 was estimated to be 1,050 based on 1986 Canada Census data and recent building permits (Sussex Consultants Ltd, 1991). The summer population is much higher, and varies depending on whether the estimate is for mid-week or weekend, whether it includes campers and motel visitors, etc. Sussex Consultants Ltd (1991) estimates that the summer weekend population in cabins and houses is approximately 4,000, and if campers and day visitors are included it would be even higher.

The majority of the population and development is concentrated at the southern and southeastern shores of the lake. Although there is some development along the northwestern portion of the lake, it is limited because it is boat access only. The northern and northeastern shores of the lake are also boat access only. Sussex Consultants Ltd (1991) estimate that in 1990 there were a total of 470 year round and 490 seasonal dwellings in the Christina Lake area.

2.4 Forestry

The Christina Lake watershed is located within the Interior Cedar Hemlock biogeoclimatic zone (BC Ministry of Forests, 1988). This zone has the widest variety of coniferous tree species of any zone in the province. Western hemlock and western red cedar are characteristic of this zone but spruce and subalpine fir are common as are Douglas fir and lodgepole pine on drier sites.

The entire watershed falls within the Ministry of Forest's Boundary Timber Supply Area (TSA), so logging plans and cutting permits are administered through the Boundary Forest District. Most of the logging that has taken place in the watershed is away from the lake itself as the shoreline is often steep and rocky, and much of it is inaccessible by road. The only major licencee operating in the area is Pope and Talbot Ltd (head office in Midway, B.C.), which operates under Forest Licence A18969. In addition to this, some logging is carried out by small businesses under authorization from the Ministry of Forests.

Logging in the Christina Lake watershed dates back to the early 1900's (Toews and Gluns, 1983). In the earlier years, much of the activity was probably selective logging (Toews and Gluns (1983). In the more recent past, the heaviest logging activity has taken place in the late 1970's and early 1980's. An indication of areas of the watershed previously logged can be obtained from Table 2, which gives areas by age class for the Christina Lake watershed.

Water quality parameters influenced by logging activity include sediment concentrations, nutrient levels, and temperature. Sedimentation is usually the principal concern. Sedimentation impacts would depend on stream channel stability, slopes, soil types, and logging and road construction practices. An example of sediment loading occurred in the Parson Creek watershed of the Christina Lake basin in 1988. A slide occurred adjacent to a logging road in the headwaters of the creek and triggered a 1.5 km debris torrent down Parson's Creek. Factors thought to contribute to the slide include an unusually quick peak spring runoff, spill over runoff from drainage structures and subsurface flow in soils. The debris torrent stopped short of Christina Lake, as a result no debris was carried in. It is probable that sediments were carried in at this time, but no water quality sampling was performed to confirm this, as the slide was not discovered for a few months.

The water chemistry of a stream has been found to be altered after logging and to a greater degree after controlled burning or wildfire (Hetherington 1987). Studies in eastern and western Canada measured concentration changes of the following dissolved nutrients and chemical

Table 2

BOUNDARY FOREST DISTRICT

AREA BY AGE CLASS FOR THE CHRISTINA LAKE WATERSHED AS OF 1990

AGE	AREA (HA)	(%)
1-20 YRS.	1514.3	3.03
21-40 YRS	895.5	1.79
41-60 YRS.	5156.5	10.31
61-80 YRS	11151.3	22.30
81-100 YRS	5504.4	11.01
101-120 YRS	6192.2	12.38
121-140 YRS	3184.5	6.37
141-250 YRS	3245.2	6.49
250+ YRS	37.3	0.07
NOT SATISFACTORILY RESTOCKED(3)	716.3	1.43
NON-FOREST(2)	12418.5	24.83
TOTAL(1)	50016	100

1. The total land base includes all private as well as crown land, parks, etc.
2. Non-forest category includes lakes, swamps, rocks, non-productive areas, etc.
3. The "not satisfactorily stocked" category includes those areas that have been deforested either by logging or by natural events such as fire, wind or insects.

Data provided by B.C. Ministry of Forests, Boundary Forest District, B.C. (Kilshaw 1991)

parameters in forest streams following harvesting or burning: calcium, magnesium, sodium, potassium, nitrogen, phosphorus, sulphate, chlorine, bicarbonate, organic substances, dissolved oxygen, colour, and pH (Hetherington, 1987 referencing the following: Feller and Kimmins 1984; Hetherington 1976; Krause 1983; Nicolson 1975; Plamondon et. al. 1982; Schindler et. al. 1980; Scrivener 1982; Singh and Kalra 1977). These concentration changes have included both increases and decreases. Hetherington (1987) states that the water chemistry parameters are generally minor and short-lived, with predisturbance conditions usually returning within 3 to 5 years. However, recorded changes have lasted as long as 9 years in a coastal British Columbia stream (Feller and Kimmins 1984 in Hetherington 1987).

Future logging activity in the Christina Lake watershed is expected to be significantly less over the next twenty years than in the last 15 years (Pers. comm. Thorpe 1991). The planned logging activity for Pope and Talbot Ltd over the next five years as obtained from their five year plan (Pope and Talbot Ltd, 1990) is summarized on Figure A1 in Appendix A. As Sutherland Creek is the source for a domestic waterworks, the Ministry of Forests Boundary Forest District is currently developing a watershed management plan for the Sutherland/Italy Creek watershed, with the input of concerned local groups. It will not be a full scale integrated watershed management plan because logging over the next 20 years will be light, so the basin is not considered critical. The plan will present resource uses and resource management objectives as well as recommend guidelines for access, silviculture and harvesting for the watershed. It is expected to be completed in April 1991.

2.5 Mining

There is no mining work being carried out in the Christina Lake watershed at this time (pers comm, Miller 1991). A previous report (Kootenay Boundary Regional District, 1975) referred to the Donna Mine on the Eva Bell M 131 claim northwest of Coryell as having produced at one time. Prospects exist east and southeast of Christina Lake for copper, zinc and chromite, but are not presently being developed (Kootenay Boundary Regional District, 1975). Light coloured biotite

granites, possibly containing uranium minerals, occur throughout the watershed.

2.6 Agriculture

Over 90% of the Christina Lake basin is classified as agricultural capability classes 6 and 7, under the Canada Land Inventory, soil capability for agriculture mapping scheme (Canadian Department of the Environment, 1973). These two classes are (6) considered suitable for producing perennial forage crops only, and (7) no capability for arable culture or permanent pasture respectively. The primary limiting factors to agriculture in these areas are shallow soil over bedrock and steep slopes. The only areas within the watershed with higher rated agricultural capability are the alluvial fans at the mouth of Sandner, Texas, McRae and Stewart creeks, as well as portions of the Sutherland Creek valley and in the immediate vicinity of the lake outlet. These regosolic (alluvial parent material) soils are class 5, which is rated as severely limited capability to produce perennial forage crops. The primary limitations to production are stoniness and a low moisture holding capacity. Two very small areas, Sutherland Creek near Fife and near the lake outlet, show an improved capability rating with irrigation. A small portion of the Sutherland Creek area, from Fife upstream to the Italy Creek confluence, is held within the Agricultural Land Reserve (Regional District of Kootenay Boundary, 1975). This very limited amount of agricultural land indicates that little increased agricultural activity can be anticipated in the future and that nutrient loading from agricultural activity is likely to remain insignificant.

3.0 HYDROLOGY AND PHYSICAL LIMNOLOGY

3.1 Hydrology of Tributaries

The major tributaries to the Christina Lake basin, in order of basin size are: McRae Creek (105 km^2), Sutherland Creek (103 km^2), Sandner Creek (75 km^2), Texas Creek (44 km^2) and Stewart Creek (17 km^2). Moody Creek (22 km^2) is tributary to Christina Creek, and drains an area immediately south of the lake basin. These streams probably all display a typical interior nival (snowmelt) hydrograph, with the single event

snowmelt runoff occurring rapidly in April and May. Flows for most of the rest of the year remain consistently low, with late summer/fall low flows followed almost without interruption by the winter low flows when all precipitation is going into snowpack storage.

Only two of the above mentioned tributary creeks have any flow gauging data, with stations located on Sutherland Creek and Moody Creek. The Sutherland Creek near Fife (WSC Station # 08NN016) recorded discharges seasonally between April and March, for the period 1960 to 1973. These data were primarily collected to monitor irrigation and domestic flow withdrawals during the summer period of peak demand, and any interpretation of the data should take the withdrawals into account (Table A2 in Appendix A). An estimate of 0.026 m^3/s for the licensed withdrawal from Sutherland Creek was made by Toews and Gluns (1983). The station Moody Creek near Christina (WSC Station # 08NN021) was maintained continuously from 1971 to 1984 (Table A3 in Appendix A). The mean annual flow from the Moody Creek basin was 0.14 m^3/s, which represents a unit runoff of 0.0064 $m^3/s/km^2$. In an attempt to estimate a more complete hydrograph for the inflow to Christina Lake, the station Big Sheep Creek near Rossland (WSC Station # 08NE039) was used (D. Toews, B.C. Ministry of Forests, personal communication). This station has a drainage area of 347 km^2 and fifty years of continuous record from 1940-1990 (Table A4 in Appendix A). If a crude estimate of flow comparison, such as total basin area is used, then the total inflow to the Christina Lake basin would be 8.27 m^3/s and the unit runoff would be 0.0168 $m^3/s/km^2$.

3.2 Christina Creek Hydrology

Christina Creek is the only outlet for Christina Lake, which drains south to join the Kettle River approximately 3 km south of the lake. The creek is reported to backwater or even reverse flow during the spring runoff, when the Kettle River peaks 2 - 3 weeks later than Christina Creek (Stringer, n.d.). This phenomenon can be corroborated by Water Survey of Canada staff (D. Lopaschuk, WSC Cranbrook, pers. comm. 1991) who have observed a backwater effect and one actual reversal in ten years of observation. The gradient of Christina Creek has not been surveyed but

is reputed to be very low. An analysis of this matter would also require stage data for the Kettle River at the Christina Creek confluences.

Water Survey of Canada reports three partial year records (1944-1946) for discharge at the station at the lake outlet (Christina Creek at the outlet of Christina Lake, station 08NN014). These data are given in Table A5 in Appendix A, with the mean monthly flow ranging from a minimum of 0.41 m^3/s to a maximum of 37.0 m^3/s, with a mean annual discharge of 6.58 m^3/s. Metered stage-discharge rating curves for 1947 and 1948 are available, and show significant differences between the two years. The station was relocated in 1978 to a site 150 m downstream on the Highway #3 bridge pier, and downstream beaver dams and in-stream debris reportedly affect water levels at the gauge site (R. Edwards, Water Management Branch, B.C. Environment, Victoria, personal communication). No new stage-discharge rating curve has been prepared since the 1940's. However, continuous water level data collection was maintained at this station by the B.C. Environment from 1945 to 1980, with several small breaks in record (Table 3). Seasonal data has been collected sporadically throughout the 1980's by B.C. Environment. These data were used to aid in the prediction of Kettle river flood timing (D. Lopaschuk, WSC Cranbrook, pers. comm. 1991).

Using the stage-discharge rating curve from the 1940's data, approximate discharges for Christina Creek were calculated to take advantage of the long record of water levels (Figure 2). These estimates should be treated with extreme caution as metered rating curves were not available for the entire period of record, and there are site constraints (ie - an unstable channel section, backwater effects) to accurately calculating discharge from these water level data. The reported flow reversal or backwater effect of Christina Creek during spring runoff (Stringer, n.d.) would also complicate discharge calculations for the creek. However, the data are useful as an indication of the relative trends in discharge over time, and also to estimate a range of lake flushing rates based on natural hydrologic variability. The other possible approach to calculating

CHRISTINA CREEK AT OUTLET OF CHRISTINA LAKE
STATION NO. 08NN014
MONTHLY + ANNUAL MEANS, WATER LEVELS IN METRES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1944	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	0.71	--------	1944
1945	--------	0.76	--------	--------	2.09	--------	--------	--------	--------	--------	--------	--------	--------	1945
1946	--------	0.76	--------	--------	--------	--------	--------	--------	--------	--------	0.56	0.65	--------	1946
1947	--------	0.69	--------	--------	--------	--------	--------	0.78	0.67	0.79	0.97	--------	--------	1947
1948	--------	--------	--------	--------	--------	--------	--------	--------	0.77	--------	0.73	--------	--------	1948
1949	0.73	0.72	0.80	1.42	--------	1.27	--------	--------	0.59	--------	--------	--------	--------	1949
1950	--------	0.74	0.78	--------	1.67	1.68	--------	--------	--------	--------	0.82	--------	--------	1950
1951	--------	--------	0.95	1.51	2.12	1.46	1.00	0.73	0.64	0.78	0.84	0.90	--------	1951
1952	0.86	0.84	0.84	1.55	--------	1.49	1.06	0.78	0.64	0.59	--------	--------	--------	1952
1953	0.68	0.73	0.77	0.99	1.89	1.95	1.33	--------	0.78	0.72	0.77	0.82	--------	1953
1954	0.81	0.79	0.84	1.07	1.94	1.68	1.30	0.93	0.90	0.84	0.88	0.97	1.08	1954
1955	0.89	0.83	0.77	1.00	1.62	1.94	1.39	0.98	0.76	--------	0.80	0.84	--------	1955
1956	0.90	0.88	0.88	--------	2.26	1.86	1.20	0.86	0.74	0.70	0.71	--------	--------	1956
1957	--------	--------	0.88	1.16	2.08	1.47	0.97	0.78	0.66	0.67	0.72	0.77	--------	1957
1958	0.80	0.90	1.18	1.56	2.06	1.57	1.07	0.80	0.68	0.67	0.70	0.77	1.06	1958
1959	0.86	0.93	0.98	1.45	2.02	1.86	1.14	0.81	0.77	0.86	0.90	0.88	1.12	1959
1960	0.85	0.84	0.88	1.61	1.89	1.75	1.09	0.77	0.69	0.69	0.73	0.77	1.04	1960
1961	0.76	--------	0.95	1.41	2.19	1.87	1.05	0.77	--------	0.63	0.66	0.71	--------	1961
1962	0.74	0.75	0.78	1.24	1.63	1.47	1.00	0.79	0.69	0.70	0.77	0.86	0.95	1962
1963	0.84	0.81	0.85	1.18	1.60	1.39	1.03	0.79	0.70	0.66	0.71	0.80	0.95	1963
1964	0.85	0.87	0.87	1.10	1.67	1.80	1.21	0.89	0.79	0.75	0.77	0.82	1.03	1964
1965	0.85	0.87	0.94	1.34	1.90	1.52	1.03	0.82	0.72	0.69	0.72	0.77	1.01	1965
1966	0.81	0.79	0.81	1.21	1.52	1.32	1.01	0.80	0.71	0.68	0.72	0.87	0.94	1966
1967	0.93	0.95	0.96	1.18	1.74	1.86	1.13	0.80	0.68	0.69	0.77	0.84	1.04	1967
1968	0.83	0.86	1.10	1.15	1.53	1.64	1.09	0.84	0.79	0.79	0.89	0.92	1.03	1968
1969	0.91	0.90	0.91	1.72	2.45	1.82	1.22	0.88	0.73	0.75	0.81	0.84	1.16	1969
1970	0.84	0.87	0.91	1.03	1.53	1.50	1.07	0.81	0.67	0.66	0.70	0.77	0.95	1970
1971	0.82	0.91	0.91	1.15	2.17	1.81	1.31	0.93	0.77	0.71	0.72	--------	--------	1971
1972	0.79	0.79	0.96	1.37	1.99	1.91	1.27	0.94	0.78	0.73	0.77	0.78	1.09	1972
1973	0.84	0.84	0.92	1.17	1.72	1.50	1.03	0.76	0.66	0.68	0.83	1.00	1.00	1973
1974	1.02	1.07	1.04	1.60	2.35	2.25	1.49	1.04	0.89	0.85	0.90	0.96	1.29	1974
1975	0.96	0.97	1.00	1.17	1.99	1.92	1.32	0.98	0.89	0.83	0.93	1.00	1.16	1975
1976	1.03	0.99	0.98	1.42	2.17	1.87	1.40	1.18	1.17	0.98	0.92	0.89	1.25	1976
1977	0.88	0.86	0.90	1.10	1.59	1.42	1.05	0.86	0.81	0.81	0.87	0.94	1.01	1977
1978	0.95	0.96	1.05	1.68	2.14	1.81	1.29	0.99	0.96	0.94	0.89	0.87	1.21	1978
1979	0.85	0.88	0.93	1.13	1.79	1.43	1.06	0.86	0.82	0.80	0.84	0.92	1.03	1979
1980	1.00	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1980
MEAN	0.86	0.85	0.91	1.30	1.91	1.68	1.16	0.86	0.76	0.74	0.80	0.84	1.07	MEAN

Table 3: Christina Creek at the outlet of Christina Lake, level data

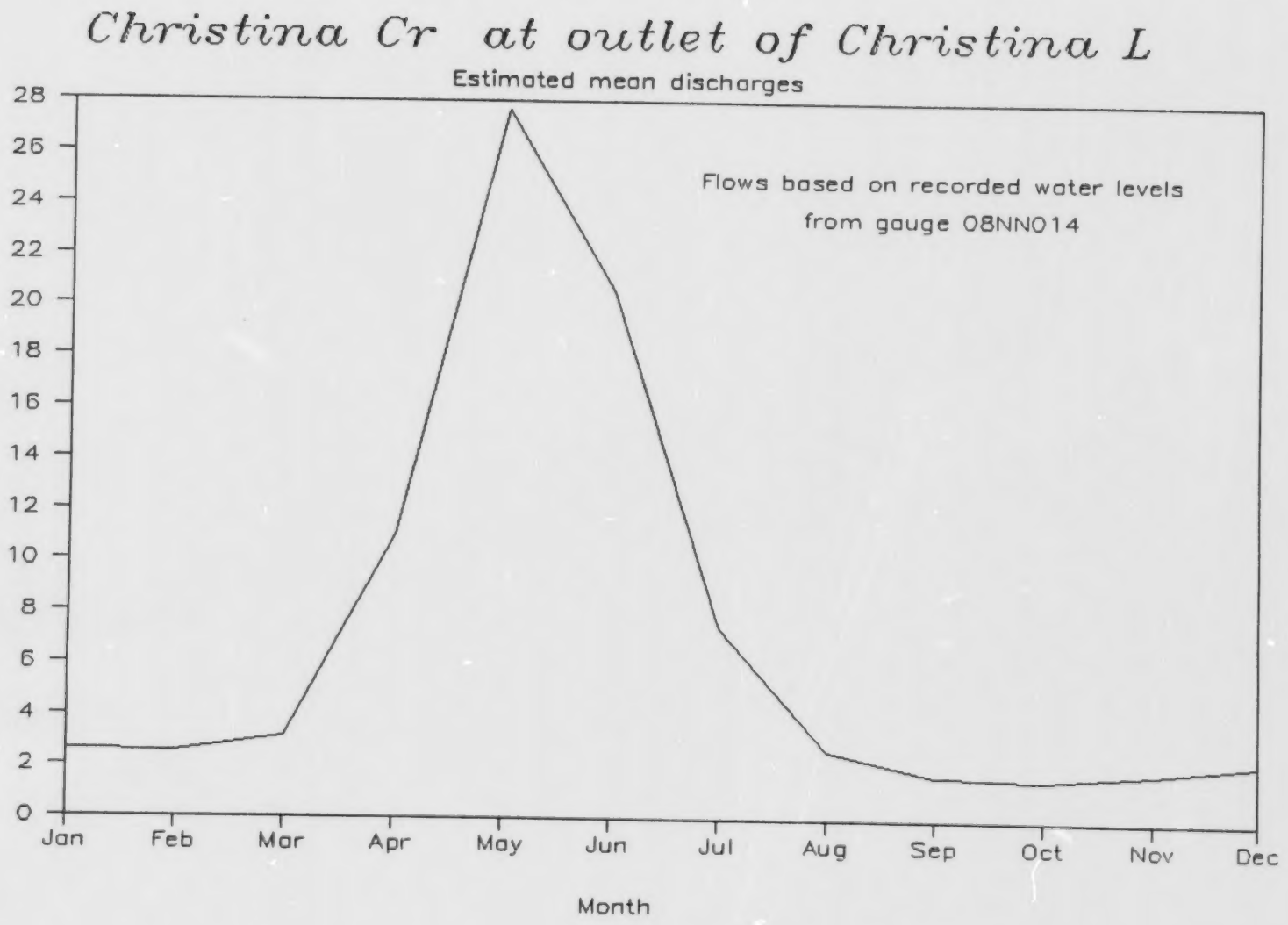


Figure 2: Christina Creek estimated outlet discharges

Christina Creek discharges would be to utilize a long period of record for Kettle and Grandby river stations above and below the Christina Creek confluence.

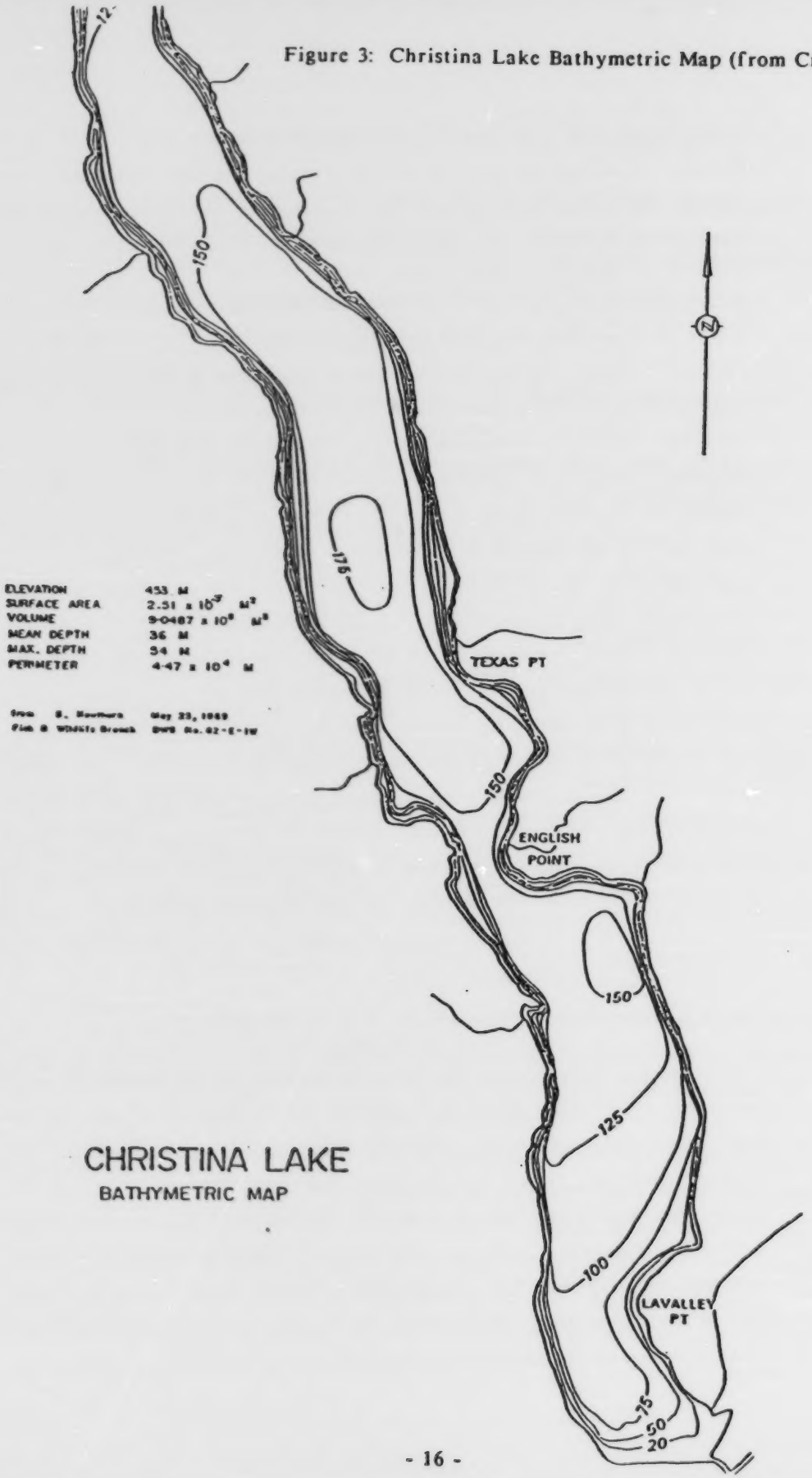
The estimated discharges for Christina Creek using the rating developed above show a relatively large amount of interannual variability, with estimated mean annual flows ranging from 4.7 m^3/s to 12.2 m^3/s for the period 1958 to 1980, with an estimated long term mean annual discharge of 7.2 m^3/s. The long-term mean monthly values indicate a typical lake outlet hydrograph, with most of the short term hydrologic events such as individual rainstorms dampened out. The creek discharge usually peaks in May, with very infrequent (4 times in 30 years) peaks in June, while September and October are typically the low flow months.

3.3 Physical Limnology

Christina Lake lies in a glacially scoured, steep sided U-shaped valley with a mean depth of 36 m and a maximum depth of 54 m (Figure 3). The lake is 18.7 km long and an average of 0.6 km wide. The lake volume is 9.0487 x 10^8 m^3, and the lake surface area is 25.1 x 10^6 m^2. Lake level data were briefly collected in 1914-1915 by the Water Survey of Canada (Christina Lake near Grand Forks, Station # 08NN017), which indicates an annual variation in lake level of approximately 1 m. The lake shores are predominantly steep sided, with very little shallow water zone, except in the vicinity of the alluvial fans of the tributary creeks and at the south end near the lake outlet. The lake freezes over for approximately 2 to 3 months each year, with the mean freeze-up date of January 25 (range December 29-February 23) and a mean break-up date of April 8 (range March 9-April 27). These dates are based on 40 years of record from the early 1900's (Allen, 1977), and more recent data would probably indicate a shorter duration of ice cover. This is corroborated by anecdotal information which reports that the lake does not freeze over entirely every year.

In years when an ice cover is formed, Christina Lake would be dimictic, exhibiting both spring and fall overturn. The lake stratifies in the summer with the epilimnion water temperatures reaching the low 20^{o}'s

Figure 3: Christina Lake Bathymetric Map (from Crozier, 1979)



Celsius range and with hypolimnion temperatures remaining at 5^{o} to 6^{o} Celsius. The lake has the reputation of being the last lake with warm summer swimming temperatures before reaching the colder glacial fed lakes of the Kootenays (Regional District of Kootenay Boundary, 1975).

A quantitative measure of the rate of replacement of the total volume of a lake is commonly sought to help define the sensitivity of the lake to nutrient loadings. A flushing rate can be calculated by dividing the lake volume by the mean discharge of the outlet stream. Crozier (1979) estimated a flushing rate for Christina Lake of 4.4 to 6.5 years, based on the Water Survey of Canada discharge data for Christina Creek and Moody Creek data. Fish and Wildlife Branch (unpublished file data) estimated a flushing rate of 3 - 4 years, which they considered to be a relatively high rate for such a large lake. Using the estimated discharge data generated from the 40 years of Christina Creek water level data, a range of flushing rates of 2.4 to 6.4 years was calculated based on the lowest and highest mean annual discharges for the period of record. Based on an estimated long term mean discharge of 7.2 m^3/s, the average lake flushing rate would be 4.0 years. Using the estimated basin inflow rate (8.27 m^3/s) calculated in Section 3.1, the flushing rate would be 3.5 years. While these calculations should not be quoted as actual or measured values, they are valuable as indicators that the flushing rate is probably in the 3 - 5 year range.

4. WATER USES

4.1 Water Licences

Water licence information for Christina Lake and its tributaries is summarized on Table A6 in Appendix A. Individual water licences by source are tabulated in the Appendix B. A total of nine licences for direct withdrawal from Christina Lake are held. Six are for domestic water use, and three are waterworks licences (one has an industrial component associated with it). Some of the major tributaries have water licences for irrigation, but the majority of the licences are for domestic and waterworks uses. Sutherland Creek also has a non-consumptive licence for water for conservation purposes.

4.2 Domestic Water Supply

Although there are 3 licences for waterworks on Christina Lake, only the Wolverton Waterworks is currently operating. This waterworks served 154 connections in 1987. The intake is located at the south end of Christina Lake, and the water is chlorinated before distribution. There are also six private licences for domestic water use on Christina Lake.

Other sources for waterworks in the Christina Lake watershed area include Sutherland Creek (Tambellini Waterworks and Sutherland Creek Waterworks) and McRae Creek (Mountain Range Waterworks). Private domestic water licences also exist on both of these creeks. Another portion of the Christina Lake community is serviced by the Christina Waterworks District which obtains its water from Moody Creek.

4.3 Recreational Use

Christina Lake is a popular recreational site due to its size and warm water temperatures. The watershed itself is relatively inaccessible and rugged so recreational activity is predominantly lake based as opposed to watershed based. Major recreational activities include swimming, fishing, camping, boating, and water skiing. The location of campgrounds and marinas in the area are shown on Figure 4.

5. WASTE DISCHARGES

5.1 Point Sources

No Waste Management permits exist for direct discharge into Christina Lake. There are two permits for discharges to ground at the south end of the lake. Permit # PE 6789, to Grey Fox Developments, is for discharge from a laundromat for a maximum of 10.9 m^3 per day. Typical laundromat effluent is high in phosphorus and sodium but low in nitrogen and with low B.O.D. The Environmental Protection Branch assessment of this permit noted that soil treatment is a good method of reducing sodium and phosphorus content of wastewater and that the overall impact on the environment from this facility is expected to be negligible. The second permit, PE 7124, to Village Services Ltd, is for discharge of effluent from a 50 unit trailer park to a ground septic

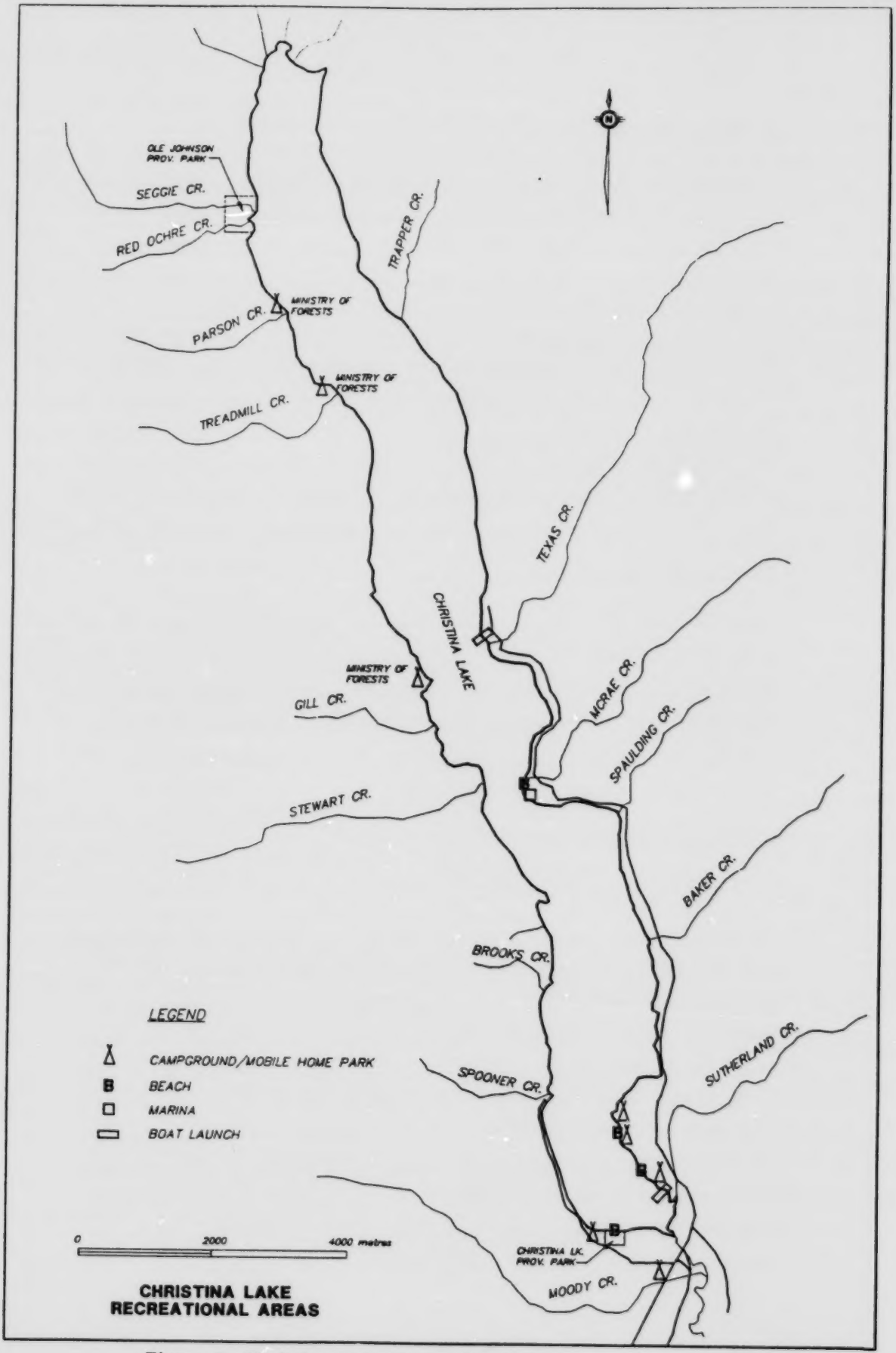


Figure 4: Christina Lake Recreational Areas

system. The quantity of effluent which is permitted to be discharged is 22.7 m^3/day. The soil percolation rate was determined to be less than one minute per inch by the Environmental Protection Branch and the groundwater table was estimated as being ten metres below the surface of the ground.

5.2 Non-Point Sources

Septic systems within the watershed are a non-point source of nutrients to Christina Lake. The majority of waste treatment facilities within the community are conventional septic tanks with subsurface effluent disposal, although some seasonally occupied properties reportedly use pit toilets and outhouses. A recent questionnaire survey of the area performed by Kerr Wood Leidal (1991) found that the majority of sewage treatment installations were poorly maintained, with less than 25 percent of the respondents indicating that their septic tanks had been emptied within the past three to five years.

Other non-point sources of nutrients to the lake would be from agricultural activities (the majority of this would be on Sutherland Creek) and from forestry activities. Marinas and boating activities could also be contributing nutrients, hydrocarbons and other materials to the lake. The sawmill which operated for fifty years before closure in the 70's, located at the lake outlet, may also be a source of contaminants. Wood waste was mixed with fill material and will continue to rot, releasing nutrients and other chemical breakdown products.

6. LAKE PRODUCTIVITY

Christina Lake is considered to be a very unproductive lake for its size by the Fish and Wildlife Branch, B.C. Environment, with a bio-index rating of 3 based on ten categories of physical, chemical and biological factors (Northcote and Larkin, 1956). By comparison, other lakes are rated higher, such as Kalamalka at 15, Oyama at 9 and Cultus at 7, with Garibaldi Lake the only other lake of 100 surveyed in British Columbia rated at 3.

6.1 Chlorophyll *a*

Chlorophyll *a* concentrations serve as an index of the phytoplankton biomass in the lake. Chlorophyll *a* concentrations measured in Christina Lake from October 1980 to October 1990 are presented in Table A7 in Appendix A, along with the range and overall average. There is good agreement between the values at the two stations. A maximum value of 4.8 mg/m^3 was recorded on March 22, 1990. This value probably captures the typical peak spring algal bloom that occurs just after lake overturn in temperate lakes.

Summer chlorophyll *a* concentrations are often used in lake trophic state calculations, so this value was calculated for Christina Lake by excluding the March and April samples. An overall lake summer average of 0.8 mg/m^3 was obtained for all samples collected from 1980 to the present. For the sampling period from 1977 to 1978 average chlorophyll *a* values range from 1.7 to 1.8 for the three lake stations. These averages included one spring sampling date. This is twice as high as the values obtained over the last decade, however, the pre 1980 samples were sampled by a different procedure.

The range of chlorophyll *a* given for oligotrophic (low productivity lakes) by Wetzel (1983) is 0.3 to 3 mg/m^3. Christina Lake would be classified as oligotrophic using this system and also based on the trophic state index for British Columbia lakes.

6.2 Phytoplankton

Phytoplankton sampling as part of B.C. Environment water quality sampling program in Christina Lake has only been conducted and analyzed on five occasions. The Fisheries Branch of B.C. Environment also has limited pre-1970 phytoplankton data on file. A summary of the water quality program data of organisms observed, listed as dominant (greater than 10 %) and non-dominant is presented in Table A8 in Appendix A. Dominant genera in algal groupings varies spatially as well as seasonally in a lake, as physical, chemical and biological conditions change (Wetzel 1983). It is therefore difficult to draw any conclusions based on the isolated sampling periods over a decade.

Two fall samples were taken, one in October of 1980 and one in October of 1990. In October of 1980 co-dominant phytoplankton species in Christina Lake included two species of diatoms (*Cyclotella kutzingiana*, and *Rhizosolenia eriensis*) and two species of green algae (*Eudorina elegans* and *Elakatothrix gelatinosa*). A non-blooming coccoid blue-green (*Comphosphaeria lacustris*) was also dominant in one sample collected at this time. The two dominant diatom species are typical of oligotrophic lakes (Wetzel 1983). A few diatom species (*Melosira italica* and *Asterionella formosa*) were also noted as dominant in October of 1990, as well as a cryptophyte (*Chroomonas acuta*) and a filamentous blue-green (*Lyngyba subtilis*).

Spring samples were collected in 1981, 1986 and 1990. In 1981, the dominant species consisted of two diatoms (*Asterionella formosa* and *Rhizosolenia eriensis*). In 1986 and 1990, diatoms were also among the dominant species (*Cyclotella glomerata* and *Stephanodiscus* in 1986, and *Asterionella formosa* and *Melosira italica* in 1990). Filamentous blue-greens were also present in appreciable numbers in both years - *Anabaena* in 1986 and *Lyngyba subtilis* in 1990.

6.3 Zooplankton

Zooplankton data collected as part of B.C. Environment water quality sampling program are presented in Table A9 in Appendix A. Again, sporadic pre-1970 data on zooplankton were collected by the Fish and Wildlife Branch and are available on file.

Dominant species in the one fall sample, taken in 1980, include the cladocerans *Bosmina longirostris* and *Holopedium gibberum*, the calanoid copepod *Epischura nevadensis*, the cyclopod copepod *Cyclops bicuspidata* and the rotifer *Kellicottia longispina*. *Kellicottia longispina* was also dominant in the spring samples taken in 1983 and 1986. Copepod nauplii and a rotifer from the family Conochilidae were also co-dominant in the 1986 sample. For the spring of 1990, *Holopedium gibberum* and the calanoid copepod *Epischura nevadensis* were co-dominant species.

Mysis relicta were released into Christina Lake in 1966, in an effort to enhance the kokanee fishery. Approximately 90,000 organisms were

released by tanker truck. Sampling done in 1975/76 and 1988/89 found a well established population of *Mysis relicta* in the lake (D. Smith, pers. comm. 1991).

6.4 Eurasian Watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*) is a non-native aquatic macrophyte that has been introduced and become a nuisance weed in a number of B.C. waterbodies. Eurasian watermilfoil (EWM) was first documented in Christina Lake by the Water Management Branch in 1986 (Retzer and Haberstock, 1990). The introduction and spread of this aquatic weed is not an indication of a deterioration in water quality, as the plant is known to take up most or all of its phosphorus requirement from the sediments where water phosphorus concentrations are low (Bole and Allan, 1978 in Crozier, 1979).

Since 1987, annual control programs have been practiced in an attempt to prevent the spread of EWM. These programs have been jointly funded by the Regional District of Kootenay Boundary and B.C. Environment. These control programs involved surveying the entire lake littoral zone and treating all *M. Spicatum* plants either by hand removal or by covering with bottom barrier to stop light from reaching the plant fragments. In 1989, the control program survey crews located 1549 plants with 4,464 stems at 38 sites (Retzer and Haberstock, 1990). Site locations and tabular information on the status of *M. Spicatum* growth at these sites are included in Appendix C. The four largest sites were Christina Sands, Sutherland Creek, Christina Creek and the South End/Drop-Off.

6.5 Fish

Salmonids are the type of fish most suited to a cold oligotrophic lake such as Christina, and kokanee (land-locked sockeye) and rainbow trout are the two salmonid species native to the system (D. Smith, B.C. Environment, Fisheries Biologist, letter, December 4, 1989). "Coarse" fish species such as sunfish, suckers, squawfish, whitefish, sculpin, shiners

and chub are also present, and largemouth and smallmouth bass and carp were introduced (B.C. Environment Fisheries Branch File).

The life history of kokanee salmon involves lake rearing for several years, and then return to the spawning stream or beach area in fall to spawn. Historically, the kokanee populations were beach spawners, but stream spawners were introduced in the 1940's in attempt to increase the populations (Stringer, n.d.). The population of beach spawning kokanee was probably depressed due to the commercial net fishery allowed on the lake during the early 1900's. Recreational and residential shoreline development also reduced the beach spawning habitat and contributed to the declining populations.

The Christina Lake tributaries which are currently utilized by stream spawning kokanee include Sandner, McRae, Sutherland and Troy creeks. Sandner Creek is considered to be the most important spawning creek, with Fish and Wildlife Branch's spawner enumeration counts indicating that approximately 50% of the kokanee population spawns in Sandner Creek. For August-September 1990, the Grand Forks Wildlife Association estimated 250 spawners in McRae Creek, 800 spawners in Sutherland Creek, and reported large numbers in Sandner (no numerical estimate was given, as the creek was full) (D. Smith memo, Fish and Wildlife Branch file). In 1987, the total spawning population on McRae Creek was estimated at 200 $\pm$ 100; Sandner Creek was estimated at 10,000 $\pm$ 500. Sutherland and McRae Creek have critically low flows and high summer temperatures, while both have man-made barriers to upstream fish migration within several kilometers of the creek mouth. Increased residential development on these creeks and the resulting problems (loss of bank vegetation, pressures to channelize and straighten the creeks) have also reduced their potential as habitat, while Sandner Creek is still relatively undeveloped. Most of the remaining tributaries to Christina Lake are considered to be unsuitable for spawning habitat as they have very steep gradients and limited supplies of adequate sized gravel.

Rainbow trout are the other important fish species present in the lake, and they too have had a history of exploitation and attempted recovery. Trout fingerlings were stocked in the lake for many years in the early

1900's, but with little success and the program was discontinued due to the lack of hatchery capability. A spring closure for rainbow trout sports fishing in the north end of the lake has been utilized in recent years as a management strategy to allow a greater escapement of trout to return to Sandner Creek. Sandner Creek represents the major spawning habitat for trout as well as the kokanee, while Sutherland and McRae creeks and lake shore habitat are also utilized.

The history of management of the fisheries resources of Christina Lake extends back to the last century. The lake supported a commercial net fishery for kokanee in the early 1900's (Stringer, n.d.), and a limited sports fishery for kokanee and rainbow trout has existed for the same length of time. The limiting factor for the salmonid populations of Christina Lake is variously reported to be the availability of spawning habitat and the low productivity of the lake. Mysis introductions were made in the 1960's to supplement food availability, and were considered successful, but did not establish as dense a population as in Okanagan Lake. While the lake is not considered to be highly productive for fish, due to the limited amount of spawning habitat and due to the low levels of nutrients, remedial measures and enhancement measures have been instituted by the Fish and Wildlife Branch of B.C. Environment. The lake has been stocked on an annual basis with rainbow trout and less commonly kokanee since the turn of the century. More recent initiatives have been directed at the apparent limiting factor for kokanee production in the system, the lack of stream spawning habitat. Spawning platforms and a fish ladder over a culvert have been constructed with varying success on McRae Creek (letter, Molnar to Campbell, Conservation Service, Ministry of Environment, 29 Sept, 1987). Other potential fisheries enhancement measures include minimum flow recommendations for tributaries during spawning and incubation, water quality protection for spawning tributaries, removal of fish barriers such as highway culverts, and protection from urban and industrial encroachments on beach spawning habitat (information from Fish and Wildlife Branch files).

7. WATER QUALITY

7.1 Data Sources

Three lake sampling stations were established by B.C. Environment in the 1970's: Station 0200078, at the south end of Christina Lake, established in 1972; Station 0200520, English Point, located approximately mid lake, established in 1976; and Station 0200519, Knob Point, at the northern end of the lake, also established in 1976. Both Stations 0200078 and 0200520 have been monitored intermittently (usually every two years, with two sampling dates per year sampled) until the present time. Sampling at Station 0200519, however, was discontinued in 1981. Most of the data collected at this station was summarized by Crozier (1979). The additional data collected in 1980 and 1981 is summarized in this report with the sampling data from the other sites. Data from stations 0200078 and stations 0200520 were obtained from B.C. Environment SEAM database.

Ministry of Health has also performed sampling at Christina Lake since the 1960's. The majority of data collected on a regular basis is beach coliform sampling data. Four sites have been monitored consistently throughout the 1980's and this data is discussed in Section 7.7, Bacteriological Quality. The locations of both B.C. Environment SEAM monitoring stations and the Ministry of Health regular beach sampling sites are shown on Figure 5.

7.2 Nutrients

Phosphorus

Total phosphorus concentration measurements have been taken since 1972 at Station 0200078 and since 1978 at Station 0200520. Prior to 1980, dissolved orthophosphate concentrations were also obtained. In 1980, however, this measurement was replaced with total dissolved phosphorus concentration measurements.

Spring temperature, dissolved oxygen, and conductivity plots (see Section 7.6) indicated that complete overturn had occurred for all years for which this data was available. Spring samples (those taken in March and

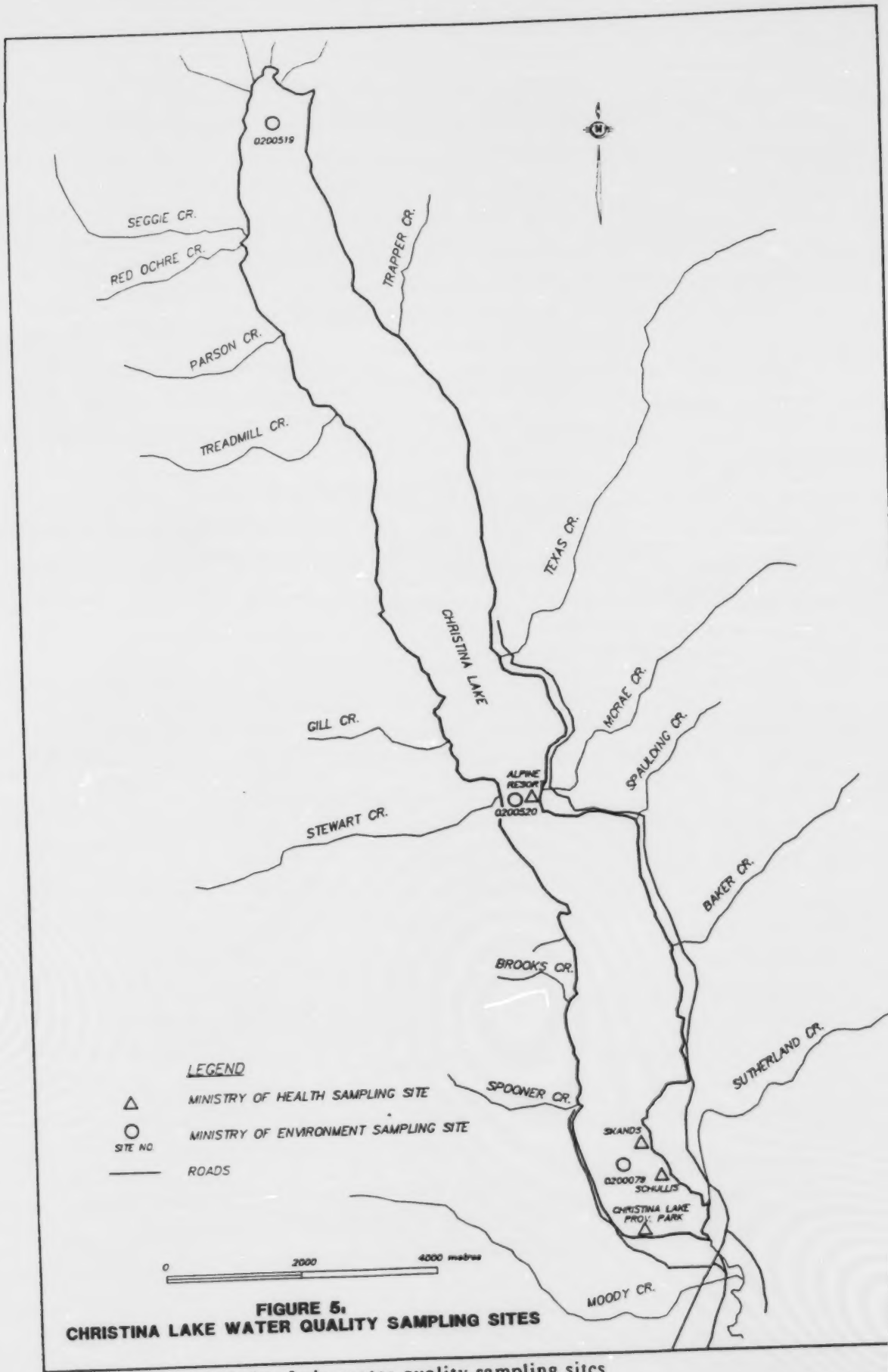


Figure 5: Christina Lake water quality sampling sites

April) were therefore plotted separately as they represented a more or less homogeneous water mass due to the recent lake mixing, rather than true epilimnetic or hypolimnetic conditions. Total and dissolved phosphorus for spring sampling dates are shown in Figure 6. This limited data shows springtime phosphorus concentrations to remain more or less the same over the last ten years. Total phosphorus usually ranged from 0.003 mg/L to 0.009 mg/L while dissolved phosphorus ranged from less than 0.003 mg/L to 0.006 mg/L. A few higher values were recorded in the spring of 1984, but these would be considered atypical. Crozier (1979) sampled only one springtime date, April 4, 1978, and obtained an average total phosphorus concentration of 0.006 mg/L, similar to what has been measured from 1980 to 1990.

Summer or fall samples, taken when the lake was fully stratified, are plotted as Figures 7 and 8 showing total and dissolved phosphorus for both the epilimnion and hypolimnion. Again, no trend is apparent either in total or dissolved phosphorus values. Most total phosphorus concentrations were below 0.016 mg/L. Values are summarized in Table A11 in Appendix A. A few higher values were recorded prior to 1986 - these did not seem to fit with other values and were near-bottom samples so perhaps sediment contamination had occurred. The highest total phosphorus value recorded from 1986 to 1990 was 0.009 mg/L. Total phosphorus values are similar to those recorded in the 1970's, with a maximum value of 0.014 mg/L being recorded and the majority of concentrations being below 0.010 mg/L.

The maximum dissolved phosphorus concentration from 1980 to 1990 was 0.008 mg/L. Values are summarized in Table A11 in Appendix A. Ninety percent of the measured values were equal to or less than the detection limit of 0.003 mg/L.

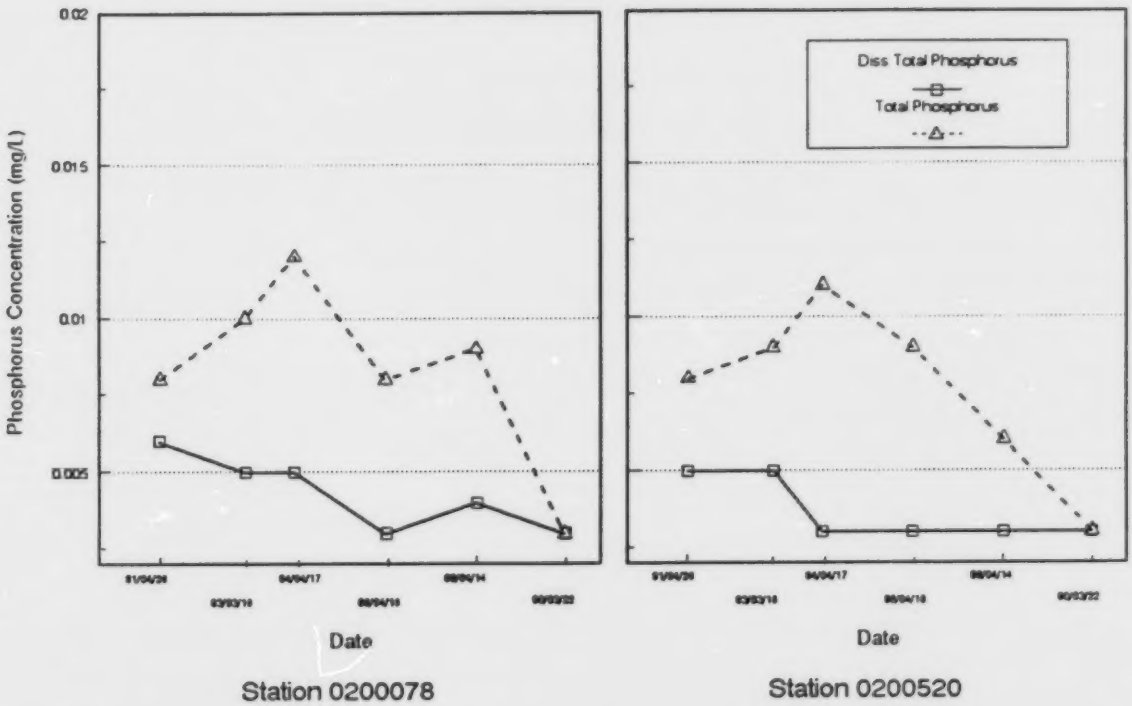


Figure 6: Spring Total and Dissolved Phosphorus Concentrations

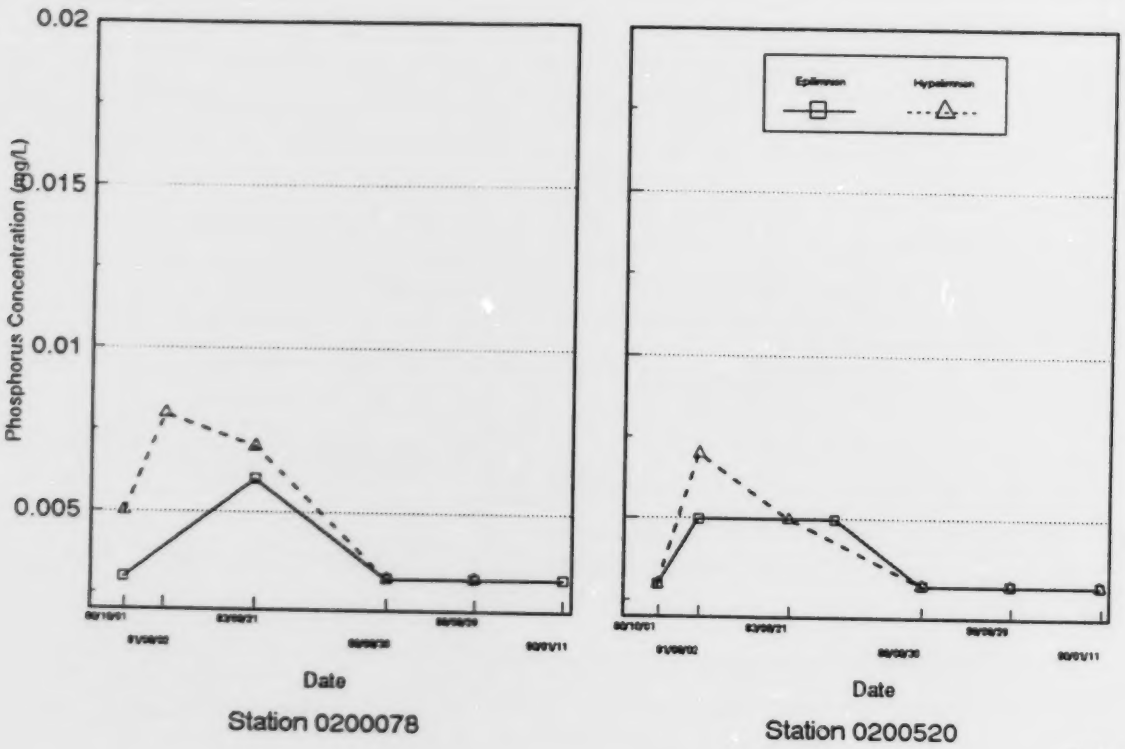


Figure 7: Stratified Lake (Summer/Fall) Total Dissolved Phosphorus

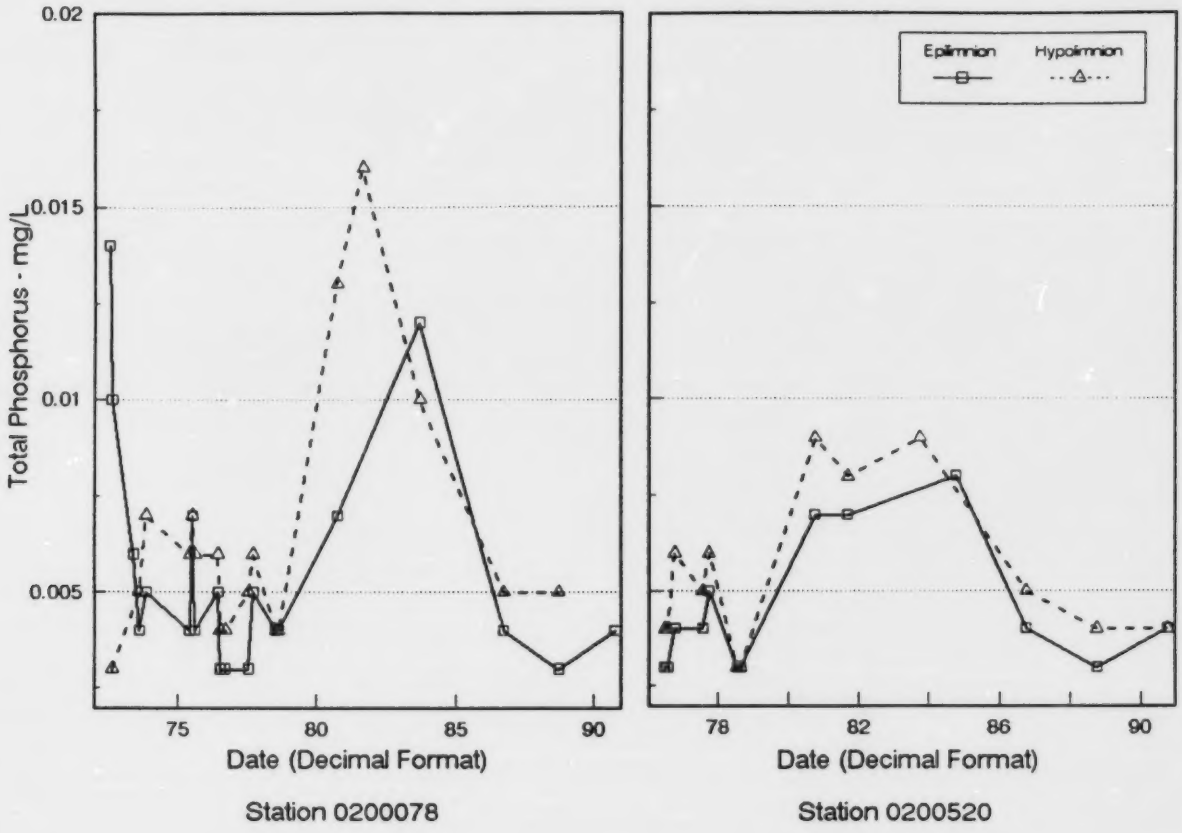


Figure 8: Stratified Lake (Summer/Fall) Total Phosphorus

Nitrogen

Organic nitrogen was the form of nitrogen present in the highest concentration in the lake. Figures 9 and 10 show the concentrations of organic nitrogen of samples collected from 1975 to 1990. Tables A13 and A14 in Appendix A summarize data available for total Kjeldahl nitrogen, dissolved ammonia nitrogen, nitrate/nitrite (NO_3/NO_2), and a calculated value for organic nitrogen. The average epilimnetic organic nitrogen concentration of samples collected from 1980 to 1990 was 0.10 mg/L and the average hypolimnetic concentration was 0.11 mg/L. Maximum values obtained were 0.14 mg/L for the epilimnion and 0.17 mg/L for the hypolimnion. These values are similar to those obtained in the 1970's, when an average (hypolimnion and epilimnion samples combined) organic nitrogen concentration of 0.11 mg/L was recorded and a maximum value of 0.90 mg/L. Samples taken during the spring before the lake had fully stratified averaged 0.09 mg/L organic nitrogen with a maximum value of 0.18 mg/L. Only one unstratified sample was taken during the 1970's.

Dissolved ammonia (NH_3) concentrations during the 1980 to 1990 sampling period were for the most part below the 0.005 mg/L detection limit for both epilimnetic and hypolimnetic stratified lake sample (see Tables A13 and A14). The exception were values ranging from 0.009 to 0.014 mg/L recorded in October of 1990. Springtime concentrations were also usually below the detection limit of 0.005 mg/L. Again there were some exceptions with a maximum value of 0.017 mg/L being recorded in April of 1981. All values recorded since 1984 have been less than the detection limit of 0.005 mg/L. These low values are similar to those recorded in the 1970's, with most ammonia nitrogen concentrations below the minimum detectable concentration of 0.005 mg/L and a few higher values being recorded.

Combined nitrate/nitrite (NO_3 and NO_2) values were also usually below the detection limit of 0.02 mg/L. The maximum concentration measured was a value of 0.04 mg/L recorded April 1988.

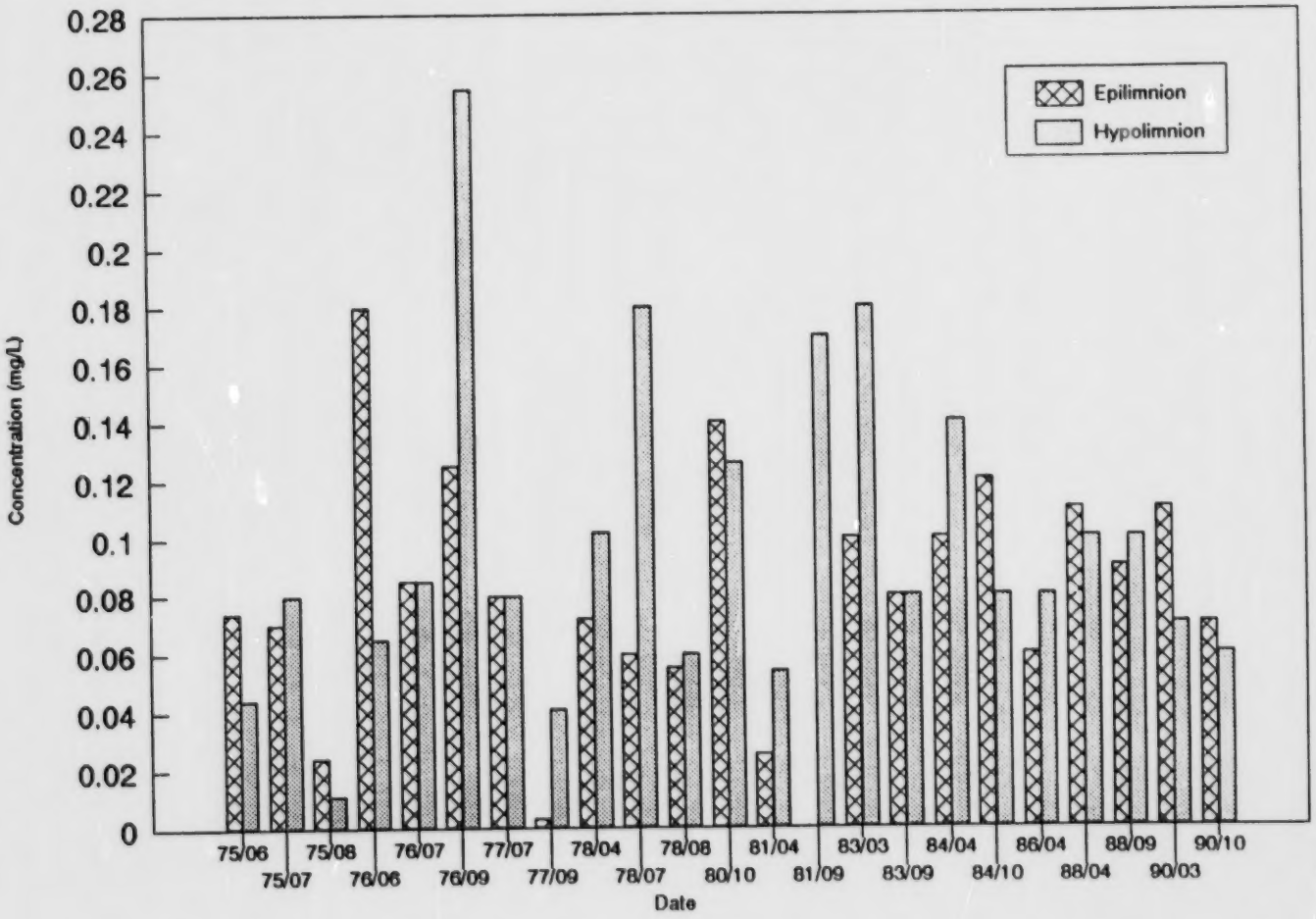


Figure 9: Organic Nitrogen Concentration (Station 0200078)

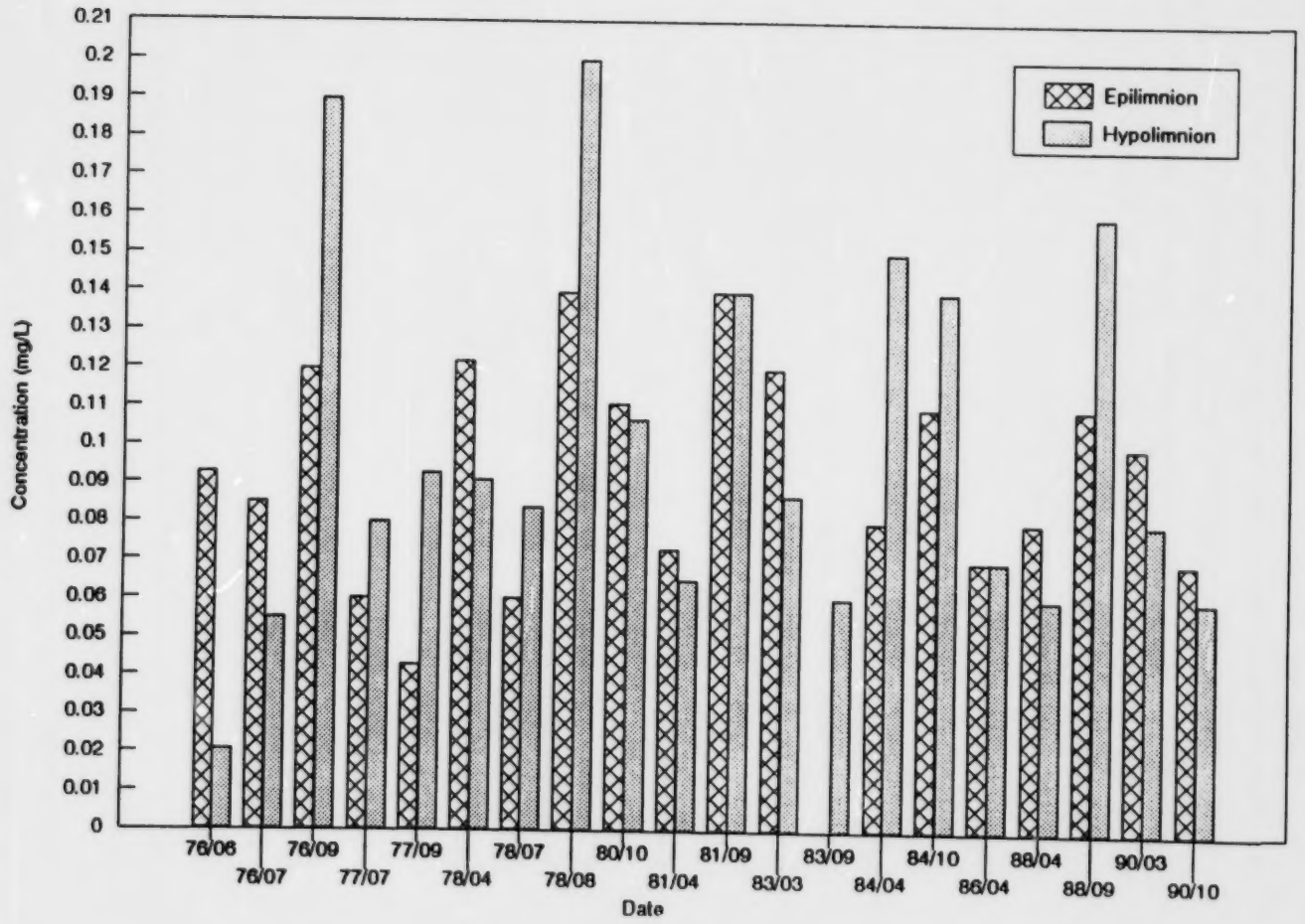


Figure 10: Organic Nitrogen Concentration (Station 0200520)

Nitrogen to Phosphorus Ratios

Average nitrogen to phosphorus (N:P) mass ratio, using these average total nitrogen and phosphorus concentrations would be 20:1. However, the spring N:P ratio has varied considerably, as shown by Table 4. Even between stations on the same date there is variation. As spring overturn is difficult to catch, this variation could be due in part to the peak spring algae bloom either occurring coincident with the sampling time or having just passed and settled out of the water column. A ratio greater than 15:1 implies phosphorus limitation.

7.3 Metals, Hardness

Dissolved hardness values were collected for Christina Lake from 1972 until 1981. Total hardness was measured only in 1984. Dissolved hardness values ranged from a maximum of 35.6 mg/L to a minimum of 27.1 mg/L, with no change over time apparent. An average total hardness value of 30.6 mg/L was determined in 1984. With these hardness values, Christina Lake water would be classified as "soft" water. Low hardness values increase acute toxicity to aquatic life from metals.

Maximum concentrations in Christina Lake are summarized in Table 5 for the following metals: arsenic, cadmium, chromium, copper, iron, lead and zinc. Concentrations were below the criteria for protection of fresh water aquatic life (Pommen, 1989) and within the guidelines for Canadian drinking water quality (1979).

7.4 pH, Alkalinity

As shown in Table A15 in Appendix A, average pH readings at each of the two sampling stations ranged from 6.8 to 8.2, with most readings being between 7 and 8, or slightly basic. Water quality criteria for pH for the protection of aquatic life are 6.5 to 9.0, and drinking water guidelines recommend a pH of between 6.5 to 8.5.

Total alkalinity values were low, ranging from 27.5 mg/L to 35.6 mg/L and with an average value of 32 mg/L. This indicates that Christina Lake would have a low buffering capacity against acidic inputs.

Table 4: Spring Total Nitrogen to Total Phosphorus Ratios

Date	Station 0200078		Station 0200520	
	N:P Hypolimnion	N:P Epilimnion	N:P Hypolimnion	N:P Epilimnion
73/05/24		23.3		
81/04/28	8.7	5.0	10.0	11.2
83/03/16	18.0	11.1	15.6	13.3
84/04/17	11.7	11.1	6.5	7.3
86/04/16	12.5	10.0	10.0	10.0
88/04/14	15.6	21.7	20.0	13.3
90/03/22	30	37	20.0	20.0

Table 5: Christina Lake Maximum Metal Concentrations, July 1972 to October 1990

Metal	Detection Limit	# of samples Collected	Maximum Value	Drinking Water Max Allowable Conc.	Criteria for Protection of Fresh Water Aquatic Life Life
Arsenic - Total	0.005	8	<0.005	0.05	0.05
	0.25	6	<0.25		
Cadmium - Total	0.0005	6	<0.0005	0.005	0.0002
	0.01	10	<0.01		
Chromium - Total	0.005	8	<0.005	0.05	0.002 for phytoplankton and zooplankton, 0.02 for fish
	0.01	10	<0.01		
Copper - Dissolved	0.001	16	0.002		
Copper - Total	0.001	24	0.002	< or = 1.0 (Aesthetics)	< or = to 0.002
	0.01	10	<0.01 *1		
Iron - Dissolved	0.04	10	<0.04		
	0.1	6	<0.1		
Iron - Total	0.01	10	0.08	< or = 0.3 (aesthetics)	0.3
	0.04	18	0.05		
	0.1	36	0.2		
Lead - Dissolved	0.001	13	<0.001		
	0.003	3	<0.003		
Lead - Total	0.001	24	<0.001	0.01	0.003 with average hardness of 30 mg/L CaCO3
	0.1	10	<0.1 *2		
Zinc - Total	0.005	14	0.017		
Zinc - Total	<0.005	24	<0.005	< or = 5.0 (aesthetics)	0.03 (tentative)
	<0.01	10	0.02		

Note: All concentrations are in mg/L

*1 Two values were recorded above the detection limit of 0.01 but were considered outliers

*2 A value of 0.1 was recorded where the detection limit was <0.1 - this value was treated as an outlier

Drinking Water Maximum Acceptable Concentrations are from:
Guidelines for Canadian Drinking Water Quality. 1989. Prepared by the Federal-Provincial Subcommittee on Drinking Water and published by authority of the Minister of National Health and Welfare

Water Quality Criteria for the protection of freshwater aquatic life are from:
Pommen, L.W. 1989. Approved and Working Criteria for Water Quality.
B.C. Ministry of Environment, Water Management Branch, Resource Quality Section.

7.5 Turbidity, Suspended and Dissolved Solids, Secchi Disk Depths

Turbidity, suspended and dissolved solids, and extinction depth (as determined by Secchi Disk) SEAM data from 1972 to 1990 are summarized in Table 6. Turbidity values in Christina Lake are very low, with measured values ranging from 0.1 to 1 NTU. The average turbidity at the south end lake station, 0.4 NTU, was slightly higher than the average of 0.3 NTU for the station at English Point.

Extinction depth data for Christina Lake are quite high, with 90 percent of recorded values being greater than 7.4 metres. The maximum depth recorded was 16 metres and the minimum was 3.2 metres, which was recorded September 2, 1981 at the south end station. The high extinction depth values and low turbidity values indicate that the water clarity of Christina Lake is very good.

Suspended solids concentrations in Christina Lake were also very low, with an average of 1.23 mg/L, and ranging from a maximum of 2 mg/L and a minimum of less than 1 mg/L.

Dissolved solids concentrations were an average of 55.8 and 53.5 mg/L at the south end and English Point stations respectively. The maximum value recorded was 62 mg/L and the minimum value was 48 mg/L.

7.6 Dissolved Oxygen, Temperature, Conductivity

Dissolved Oxygen

Dissolved oxygen profiles for Christina Lake for spring and summer/fall samples in 1981 and 1988 are shown in Figures 11 and 12. Dissolved oxygen profiles for fall of 1980 and spring of 1986 are shown in Figures A2 and A3 in Appendix A. Profiles for each of the late summer and fall sampling dates and stations show hypolimnetic dissolved oxygen concentrations to remain undepleted and suitable for salmonid growth.

Minimum dissolved oxygen concentrations observed from 1980 to 1990 were 8.0 mg/L for Station 0200078 and 7.28 mg/L for Station 0200520. Ninety percent of values observed at both Station 0200078 and Station 0200520 for the same time period were greater than 8.2 mg/L. This data

Table 6: Christina Lake Extinction Depth, Turbidity and Solids, July 1972 - October 1990

Sampling Site	South End 0200078				English Point 0200520			
Parameter	Max	Min	Mean	N	Max	Min	Mean	N
Depth, Extinction (m)	16	3.2	10.3	30	15.8	6.4	10.6	21
Total Residue @ 105 C (mg/L)	64	52	55.8	34	62	52	56.4	17
Filterable Residue (mg/L) (Dissolved Solids)	62	48	55.8	28	60	50	53.5	12
Non-Filterable Residue (mg/L) (Suspended Solids)	2	< 1	1.25	8	2	< 1	1.2	9
Turbidity (NTU)	1	0.1	0.4	33	0.5	0.1	0.3	17

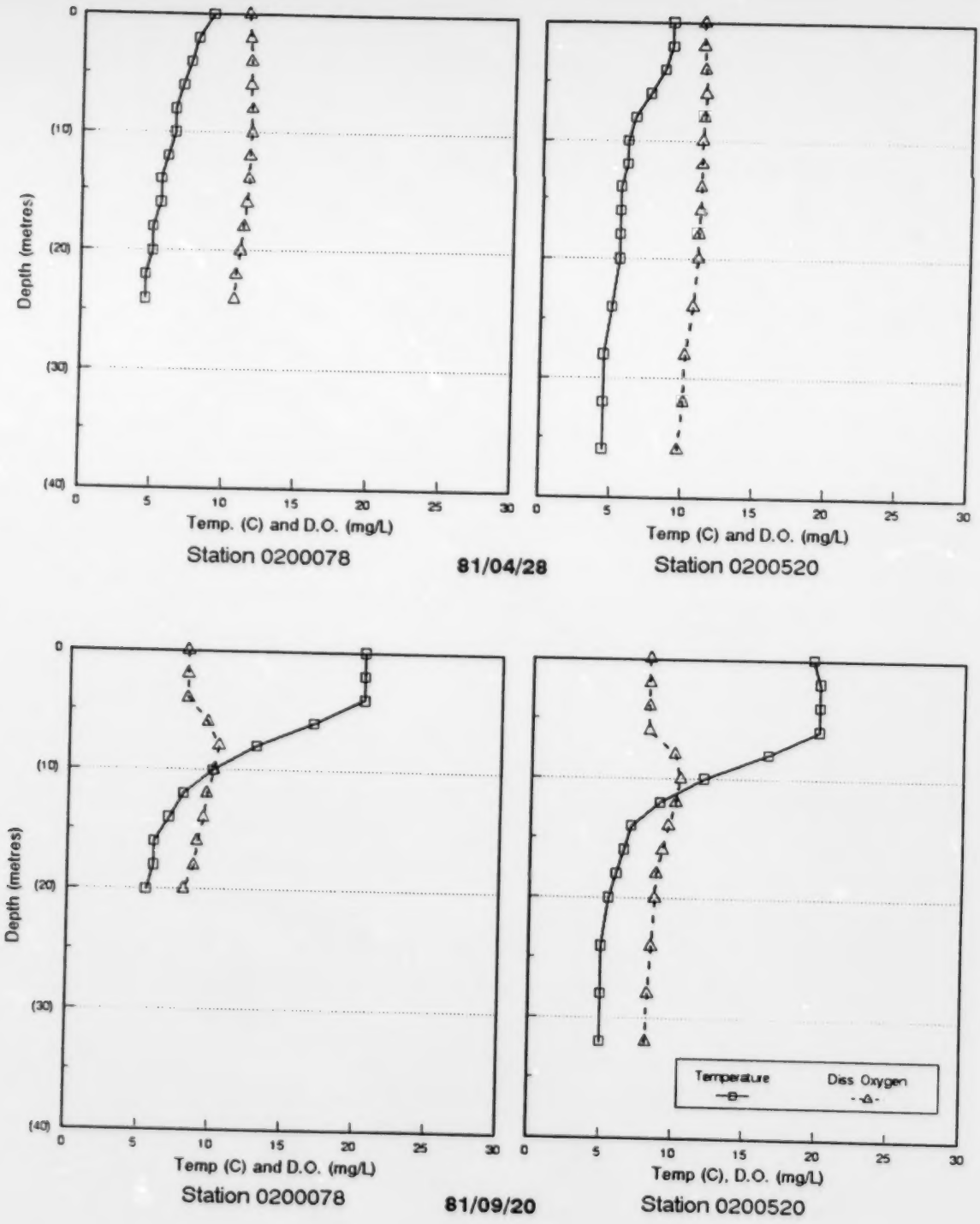


Figure 11: 1981 Christina Lake Temperature and Dissolved Oxygen Profiles

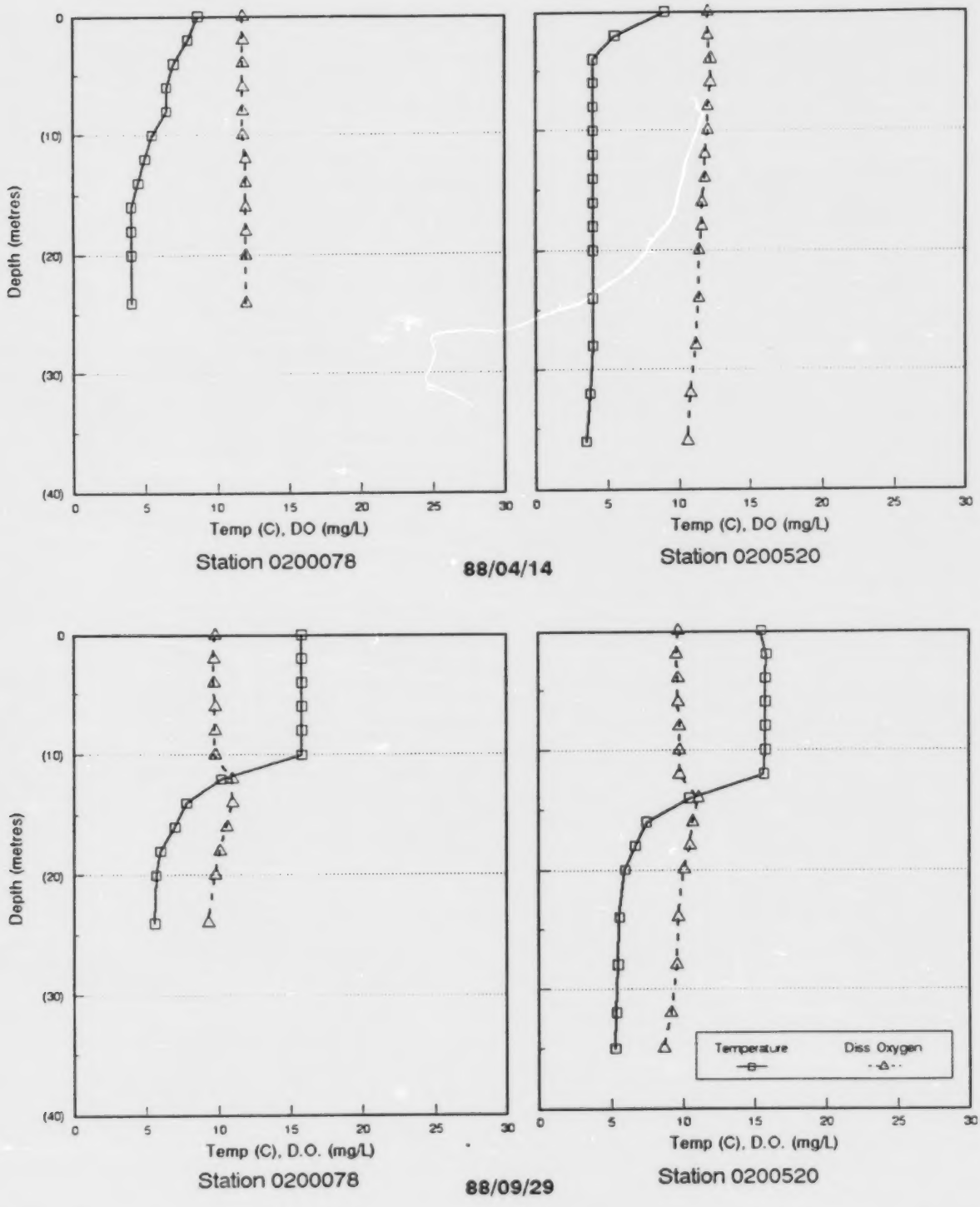


Figure 12: 1988 Christina Lake Temperature and Dissolved Oxygen Profiles

is summarized and compared to data collected in 1977 and 1978 in Table 7.

The increase in dissolved oxygen concentrations at the metalimnion for the fall samples taken in 1980, 1981, and 1988 suggest a concentration of algal biomass at this depth. This was also noted by Crozier (1979) for the data collected in the 1970's.

Conductivity

Conductivity profiles taken in 1980 and 1981 are plotted as Figure A5 in Appendix A.

Temperature

Temperature profiles for Christina Lake from available data obtained from 1980 to 1990 are shown in Figures 11 and 12, and A2 and A3 in Appendix A. April sampling dates show the lake just beginning to stratify, while the September and October profiles show strong stratification. These fall profiles show the thermocline to be located at a depth of 8 to 12 metres.

7.7 Bacteriological Quality

Since 1980, the Central Kootenay Health Unit has carried out seasonal coliform sampling on four major bathing beaches on Christina Lake (as shown on Figure 5). Available data from 1986 summarized by location and date is given in Table A16 in Appendix A. None of the samples from 1986 to 1990 exceeds the guideline for Canadian recreation water quality (1983) which states "The geometric means of not less than 5 samples taken over a 30-day period should be less than 200 fecal coliforms/100 ml". Ninety-six percent of the readings since 1986 have not exceeded 10 MPN/100 ml or 10 fecal coliform units/100 ml, and the maximum reading recorded for this time period was 150 MPN/100 ml.

Fecal coliform data was also collected at the SEAM mid lake sampling stations 0200078 and 0200520 from 1980. This data is shown in Table A17 in Appendix A. All readings were less than 2 fecal coliform units

Table 7: Comparison of Dissolved Oxygen (D.O.) Values

Station	Min. D.O. Concentration (mg/L)		90th Percentile D.O. (mg/L)	
	1977-78	1980-90	1977-78	1980-90
0200078	7.0	8.0	8.2	8.2
0200520	7.0	7.28	7.6	8.2

per 10 millilitres, well within the guideline for recreational bathing water.

Results of both the Ministry of Health and B.C. Environment coliform sampling from 1980 to 1990 are similar to data presented in earlier studies. Studies conducted in 1967 and 1970 by the Ministry of Health (as presented in Regional District of Kootenay Boundary, 1975) showed very low fecal coliform counts. Another Ministry of Health study (Philion 1981) summarized bacteriological data collected from weekly sampling conducted from May to October 1978. Six of the sampling locations were close to beaches, residences or commercial establishments bordering the lake while two served as control and were located away from development. During this time 95 percent of the samples taken had fecal coliform counts less than 7 MPN/100 ml. For total coliforms, 95 percent of samples had less than 33 MPN/100 ml. Some samples exhibited total coliform numbers of greater than 100 MPN/100ml, but these samples had low levels of fecal organisms, which indicates that there was no recent fecal contamination at the location on sample days (Philion 1981).

There are 6 private drinking water licences and three licences for domestic waterworks on Christina Lake. Guidelines for Canadian Drinking water (1989), which are used by BC Ministry of Health, recommends that drinking water delivered to the user should contain zero fecal coliforms. No guidelines are given for raw water supply. Wolverton Waterworks, the only waterworks currently withdrawing water from Christina Lake, chlorinates the water, and this is regularly tested by the Ministry of Health Inspector (Thompson, pers. comm. 1991). The waterworks is considered an acceptable supply of drinking water.

7.8 Tributary Water Quality Sampling

Several of the major tributaries to Christina Lake have had water quality samples taken in the past, primarily to check for nutrient input to the lake. This information is available on B.C. Environment EQUIS database fiche.

Sandner Creek (Station # 0200518), Stewart Creek (Station # 0200538) and McRae Creek at Christina Lake (Station # 0200517) were sampled once in 1978 for nutrients (Crozier, 1979). Sutherland Creek (Station # 0200079) was sampled for a number of parameters (including nutrients and metals) from 1972 to 1978. Sutherland Creek was also sampled in 1982 for turbidity and nutrients. The 1982 results are summarized in Table A18 in Appendix A. Results of tributary monitoring showed total and orthophosphorus concentrations to be significantly higher in Sutherland Creek than in any of the other tributaries. Average total phosphorus concentrations for Sutherland Creek was 0.035 mg/L (Crozier 1979). For Stewart, McRae and Sandner Creek total phosphorus values were found to be 0.016, 0.018 and 0.005 mg/L respectively. Crozier (1979) suggests that there is a strong possibility that Sutherland Creek flow "short-circuits" the lake because of its close proximity to the lake outlet (Christina Creek). Other evidence suggests that this is probably not the case. Table 2 shows Sutherland Creek flow to peak in May, at which time the surface of the lake would be warming. The creek water would probably be colder and samples show higher total dissolved solids than Christina Lake water. This implies inflow would be to an intermediate depth or along the bottom, thus any short circuit would not likely be direct.

Parson Creek and Treadmill Creek, located on the north-western side of Christina Lake, were sampled in 1988 by the Ministry of Health. Selected water quality results are shown in Table A19 in Appendix A. Nutrient levels in both of these creeks were low on the sampling date.

8. LAKE TROPHIC STATUS AND CARRYING CAPACITY

Based on chlorophyll *a*, total phosphorus, and total nitrogen, and using the classification ranges presented in Wetzel (1983), Christina Lake would be classified as oligotrophic, or low productivity. Mean chlorophyll *a* concentrations are discussed in Section 6.1. The mean total phosphorus concentration for the entire period of record is 0.006 mg/L. For the period from 1980 to 1990, springtime mean total phosphorus concentration is 0.008 mg/l and epilimnion concentration is 0.006 mg/L.

The mean total nitrogen concentration is 0.12 mg/L. These low nutrient values fall within the range for oligotrophic lakes.

In 1979 a rough estimate was made by Crozier of the increase in phosphorus loading required to elevate Christina Lake from its low productivity oligotrophic classification to mesotrophy. This estimate was made using Vollenweider's phosphorus loading versus mean depth/water residence time relationship (Vollenweider, 1974). Phosphorus loading to Christina Lake was estimated based on tributary concentrations to be in the range of 2600 to 3900 kg/year. It was speculated that an increased total phosphorus loading of approximately 1000 - 1500 kg per year could move Christina Lake into mesotrophic status. It should be noted that estimating actual phosphorus loadings to a lake is difficult, especially with the limited data available. Applying this data to models to extrapolate loading rates in order to increase trophic status is also very difficult, and models provide only broad estimates, as they are usually not lake specific.

Phosphorus loadings from tributaries could not be updated for this report, as the only sampling on major tributaries that has taken place since that time was for Sutherland Creek in 1982, and this sampling showed no change over previous values. However, it is possible that creek nutrient loadings have increased since that time. Also, the loadings from non-point sources around the lake have probably increased due to increased development. Kerr Wood Leidal (1991) give a worst-case potential phosphorus loading to the lake from septic tank effluent to be 5000 kg/year. This estimate seems an order of magnitude too high, from an overview viewpoint, based on evaluation of the assumptions (Nordin 1991 pers. comm). The estimate was based on simplified assumptions that only 10 % of phosphorus is removed in the septic tanks, and all effluent migrates to the lake, from an annual population of 3000 (5000 people for 6 months in summer and 1000 people for the remaining 6 months) producing 5 grams of phosphorus per person per day.

Current water quality data for Christina Lake show no increase in nutrient levels or change in the trophic status of the lake. This suggests that phosphorus loadings have not yet increased by the 1000 - 1500 kg

estimated by Crozier (1979) to move the lake to mesotrophic status or that the model may not be accurate enough in this case, due to the difficulties in making estimates as discussed previously. If additional information on tributary loadings to the lake is collected, the model could be updated. Flushing rates should also be re-examined, as the flushing rate of 4.4 to 6.5 years by Crozier (1979) looks high in light of the average lake flushing rate of 4.0 years calculated in Section 3.3 of this report.

9. REVIEW OF CURRENT SAMPLING PROGRAM

The current water quality monitoring program consists of two water quality stations sampled intermittently (usually every two years) by B.C. Environment and seasonal bacteriological sampling at 4 beach sites by Ministry of Health. These samples would be sufficient to determine broad long term trends in the parameters of interest (ie - nutrients) but they are inadequate to monitor seasonal or other shorter term impacts. It is also difficult to make comparisons from year to year with varying sampling dates when seasonal trends are not defined. Spatial patterns of water quality such as possible near-shore problems cannot be adequately described with only two sampling sites.

10. DRAFT TERMS OF REFERENCE FOR MONITORING PROGRAMS

10.1 Short Term Monitoring

A short term monitoring program should be conducted to achieve the following objectives: to confirm the validity of the long term sampling program by investigating spatial and temporal variability; and to collect relevant data that hasn't been investigated before.

The data presented in this report shows that most of the important parameters for assessing overall lake water quality trends have been collected. A brief review of references relating to development effects on lake water quality in other jurisdictions (Regional District of Fraser-Fort George, 1980; Michalski and List 1986) indicates that the productivity indices data collected for Christina Lake are similar.

There are, however, a few specific areas that could be investigated to help assess nutrient loadings to the lake. These include:

* tributary water quality: the major tributaries to Christina Lake could be sampled on a short term basis to determine nutrient and other loadings to the lake. Most of the tributaries have only been sampled once, in 1978, and the only tributaries which were sampled since 1982 are Parson and Treadmill Creeks. Regular sampling over a one year period will both help estimate lake loadings and provide a baseline of tributary water quality. The important parameters to be monitored include: nitrogen (ammonia, Kjeldahl and nitrate and nitrite), total and dissolved phosphorus, total dissolved solids, suspended solids, and turbidity. Spot flow discharge measurements also need to be done in order to estimate loadings.

* lake outflow rates: the possibility of re-establishing a stage-discharge rating curve for the Christina Creek station could be investigated, so as to permit a more accurate calculation of lake outflow rates, and thus lake flushing rates. This would help to estimate the lake's sensitivity to increased nutrient loadings. The alternative could be to use mainstem Kettle River stations above and below the Christina Creek confluence to calculate Christina Lake outflows. These options could be explored with Water Management Branch of B.C. Environment and/or Water Survey of Canada.

* macrophyte mapping: Although Eurasian watermilfoil mapping is done on an annual basis, mapping of other macrophytes has not been performed since 1974. Since there has been some concern expressed about water weeds, perhaps this could be incorporated as part of the Eurasian milfoil control program.

The second objective of the short term monitoring program would be to describe spatial and temporal variability of lake water quality and productivity parameters. The purpose of this component is to confirm the validity of the long term sampling program and to identify site specific or seasonal problems which may have been missed by the twice yearly sampling. It will also help establish a good baseline for water

quality index parameters by revealing seasonal trends and data ranges. This monitoring could include:

* water clarity, nutrient, and chlorophyll *a* monitoring at an expanded number of stations, including some near shore areas. This monitoring should also take place over an entire season on a regular basis in order to determine temporal variability. At least one other deep water station in the middle to northern end of the lake should be monitored. This would help determine if Station 0200520, English Point, is representative or if it is being affected by flow from nearby McRae or Stewart Creeks. Near shore sampling areas could include two sites on developed shoreline and one control site in an undeveloped area. Sampling at these sites should involve taking samples on a transect from the shallows to a depth of 15 to 20 metres.

10.2 Long Term Monitoring

The purpose of the long term sampling program would be to ensure that an adequate database is collected to monitor trends and assess compliance with guidelines and objectives. The long term monitoring program would involve measuring water quality parameters of concern (such as nutrients, chlorophyll *a*,) over the long term in order to identify any changes in overall lake water quality. Fewer parameters could be sampled than are measured presently, but perhaps frequency could be increased to a yearly basis. The existing water quality stations should be sampled in order to provide long term continuity, as long as these stations appear form the short term monitoring program to be representative of overall lake water quality. This program would also monitor for compliance with objectives once they have been set. A component of the long-term program should utilize assistance from local citizens. They could provide assistance by collecting measurements such as water clarity on a more regular basis. This program can be better defined when results of the short term program have been assessed.

11. CONCLUSIONS

Water quality data collected since 1972 in Christina Lake shows the overall water quality to be good. Comparison of data collected from 1980 to 1990 with that presented in the 1979 MOE report on water quality (Crozier 1979) shows water quality parameters to be relatively unchanged.

Relevant specific findings of this study include:

1. Nutrient levels in the lake are low. Spring total phosphorus concentrations averaged 0.008 mg/L and summer epilimnetic phosphorus concentrations averaged 0.006 mg/L. Total nitrogen concentrations averaged 0.10 mg/L both for spring and summer epilimnetic samples collected between 1980 and 1990. These concentrations are similar to those observed in the 1970's.

2. Christina Lake would be classified as an oligotrophic (low productivity) lake. The mean summer epilimnetic chlorophyll *a* concentration is low at 0.8 mg/m^3, and other trophic state indices such as nutrients are low.

3. The bacteriological water quality of Christina Lake is good, with all beach samples taken by the Ministry of Health since 1986 being within the guideline for Canadian recreation water quality.

4. Heavy metal concentrations were below the maximum allowable criteria for protection of freshwater aquatic life (Pommen 1989) and within the guidelines for Canadian drinking water quality (1989).

5. The flushing rate of Christina Lake was estimated to be 4.0 years based on Christina Creek long term mean discharge estimated from water level data. This is lower than previously calculated estimates of 4.4 to 6.5 years (Crozier 1979) based on 1944-1946 Water Survey of Canada data for Christina Creek and data for Moody Creek. This area requires further investigation.

6. A short term monitoring program should be conducted to determine seasonal variance in water quality parameters such as nutrient levels and water clarity and to confirm the validity of the long term

monitoring program. Although there was no trend in water quality over the time period examined there was quite a bit of variance. Long term monitoring should be conducted to ensure the early identification of any potential problem areas.

REFERENCES

Allen, W.R.T., 1977. Freeze-up, break-up and ice thickness in Canada. Atmospheric Environment Service, Fisheries and Environment Canada, 185 pp.

Anon. 1973. Christina Lake - Tributaries. Report in B.C. Ministry of Environment Christina Lake Fisheries File. Penticton Office, B.C. Ministry of Environment.

B.C. Ministry of Environment, 1980. Summary of snow survey measurements in British Columbia, 1935-1980. Inventory and Engineering Branch, B.C. Ministry of Environment. 219 pp.

B.C. Ministry of Environment, 1989. Field Criteria for Sampling Effluents and Receiving Waters. report by Bollans, Crozier and McQuaker, Waste Management Branch, 17 pp.

Bole, J.B. and Allan, J.R. 1978. Uptake of Phosphorus from Sediment by Aquatic Plants, *Myriophyllum spicatum* and *Hydrilla verticillata*. Water Research Vol 12, pp 353-358.

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian Water Quality Guidelines. Inland Waters Directorate, Environment Canada, Ottawa, Ontario. 357 pp

Canadian Department of the Environment, 1973. Soil capability for agriculture, Canada Land Inventory, Grand Forks 82E/SE, 1:125,000

Crozier, R. 1979. Report on Christina Lake Water Quality and Primary Productivity. Ministry of Environment, Waste Management Branch, Kootenay Region.

Dillon, P.J. and F.H. Rigler 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. Journal of Fisheries Research Board of Canada. vol 32 p 1519-1531.

Environment Canada, no date. Canadian Climate Normals, 1951-1980, Temperature and Precipitation, British Columbia. Atmospheric Environment Service, Environment Canada.

Guidelines for Canadian Drinking Water Quality. 1989. Prepared by the Federal-Provincial Subcommittee on Drinking Water and published by authority of the Minister of National Health and Welfare.

Hetherington, E.D. 1976. Dennis Creek, a look at water quality following logging in the Okanagan Basin. Can. For. Serv. Inf. Rep. No. BC-X-147.

Hetherington, E.D. 1987. The Importance of Forests in the Hydrological Regime. In Healey, M.C. and R.R. Wallace (eds.) Canadian Aquatic Resources. The Rawson Academy of Aquatic Science, Department of Fisheries and Oceans, Ottawa, Canada.

Holland, S.S. 1976. Landforms of British Columbia: A physiographic outline. B.C. Department of Mines and Petroleum Resources, Bulletin #48. 138 pp.

Kerr Wood Leidal Associates Ltd. In Draft 1991. Report on Water Supply and Wastewater Disposal at Christina Lake. Prepared for the Regional District of Kootenay Boundary and the Christina Lake Study Committee.

Kilshaw, David. 1991. Planning Information obtained from the Ministry of Forests database, Boundary Forest District, Grand Forks, B.C.

Krause, H.H. 1982. Effect of forest management practices on water quality - a review of Canadian studies, p. 15-29. In Proc. Can. Hydrol. Symp. '82. National Research Council of Canada. Ottawa, Ont.

Michalski, M.F.P. and R. List 1986. Limnology and Official Plans: The Muskoka, Ontario Experience. Canadian Water Resources Journal, vol 11 #2, p 41-54.

Miller, R. 1991. Personal Communication with Red Miller, Mining Inspector with the Nelson District of the Ministry of Energy, Mines, and Petroleum Resources.

Minister of National Health and Welfare. 1983. Guidelines for Canadian Recreational Water Quality. Prepared by the Federal-Provincial Working Group on Recreational Water Quality of the Federal-Provincial Advisory Committee on Environmental and Occupational Health. Supply and Services Canada.

Nicolson, J.A. 1975. Water quality and clearcutting in a boreal forest ecosystem, p. 733-738. In Proc. Can. Hydrol. Symp. - 75. National Research Council of Canada, Ottawa, Ont.

Nordin, R.N. 1985. Water quality criteria for nutrients and algae. Technical Appendix, B.C. Ministry of Environment.

Nordin, R.N. 1991. Personal communication with Dr. R. Nordin, Senior Biologist, Water Quality Unit, Water Management Division, Ministry of Environment.

Northcote, T.G. and P.A. Larkin, 1956. Indices of Productivity of B.C. Lakes. J. Fish. Res. Bd. Canada 13 (4):515-540.

Plamondon. A.P., A. Gonzalez, and Y. Thomassin. 1982. Effects of logging on water quality: comparison between two Quebec sites. p. 49-70. In Proc. Can. Hydrol. Symp. '82. National Research Council of Canada. Ottawa, Ont.

Pommen, L.W. 1989. Approved and Working Criteria for Water Quality. Ministry of Environment, Water Management Branch, Resource Quality Section.

Pope and Talbot Ltd. 1990. 5 Year Development Plan, Forest Licence A18969, Boundary TSA.

Prepas, E.E. and D.O. Trew 1983. Evaluation of the phosphorus - chlorophyll relationship for lakes off the Precambrian shield in western Canada. Canadian Journal of Fisheries and Aquatic Sciences, vol 40, p 27-35.

Regional District of Fraser-Fort George 1980. Lake shore Guidelines. policy document of the Lake shore Management Committee, Regional District of Fraser-Fort George, 62 pp.

Regional District of Kootenay Boundary.. 1975. The Christina Lake Study. The Planning Department, Regional District of Kootenay Boundary, Trail.

Retzer, B. and D. Haberstock. 1990. the 1989 Christina Lake Eurasian Watermilfoil Control Program. Littoral Resources Unit, Water Management Branch, Ministry of Environment, B.C.

Schindler, D.W., R.W. Newbury, K.G. Beaty, J. Prokopowich, T. Ruszczynski, and J.A. Dalton. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. Can. J. Fish. Aquat. Sci. 37:328-334.

Scrivener, J.C. 1982. Logging impacts on the concentration patterns of dissolved ions in Carnation Creek, British Columbia, P. 64-80. In G.F. Hartman (ed.) Proc. Carnation Creek Workshop, a 10 year review. Pacific Biological Station, Nanaimo, B.C.

Singh, T. and Y. Kalra. 1977. Impact of pulpwood clearcutting on stream water quality in west central Alberta, p. 272-284. In R. H. Swanson and P.A. Logan (ed.) Proc. Symp. Alberta Watershed Research Program. Can. For. Serv. Inf. Rep. NOR-X-176.

Smith, D. 1991. Personal Communication with Dave Smith, Fisheries Biologist, Fish and Wildlife Branch, Penticton Office, BC Ministry of Environment.

Stringer, G.E. no date. Preliminary report on Kokanee fishing in Christina Lake, MOE, Fish and Wildlife Branch, Penticton.

Sussex Consultants Ltd. 1991. Christina Lake Restructure Study. draft report to Regional District of Kootenay Boundary

Thompson, L. 1991. Personal communication with Lorraine Thompson, Health Inspector, Central Kootenay Health Unit, Grand Forks.

Thorpe, D. 1991. Personal communication with Doug Thorpe, Timber Resource Officer, Boundary Forest District, Grand Forks.

Toews, D. and D.R. Gluns. 1983. Sutherland/Italy Creek Preliminary Hydrological Overview. Hydrology Section, Ministry of Forests, Boundary Forest District, Nelson, B.C.

Water Survey of Canada. 1989. Historical Streamflow Summary to 1988, British Columbia. Environment Canada, Ottawa, 1056 pp.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Toronto.

APPENDIX A

TABLES AND FIGURES

Table A1: Farron Snow Course Data (B.C. MOE, 1980)

SNOW COURSE DATA (REGULAR MEASUREMENTS)

NO. 2B02 FARRON NO. 1 REGION: COLUMBIA

ELEV. 1220 METRES LAT. 49-16 LONG. 118-08 DRAINAGE: LOWER COLUMBIA

JANUARY 1			FEBRUARY 1			MARCH 1			APRIL 1			YEAR	MAY 1			MAY 15			JUNE 1			JUNE 15		
DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm		DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm
									03-28	117	401	1938												
									03-29	63	218	1939												
			01-30	56	117	02-27	104	244	03-30	66	231	1940												
			01-29	89	218	02-26	91	249	03-28	20	58	1941												
			01-29	66	114	02-26	89	180	03-30	58	165	1942												
			01-28	107	229	02-25	97	277	03-30	99	239	1943												
			01-31	69	163	02-27	81	211	03-29	63	198	1944												
			01-28	84	188	02-25	97	262	03-26	117	351	1945												
			01-30	117	310	02-27	132	389	03-29	114	399	1946	04-30	20	74									
			01-30	109	262	02-26	84	277	03-31	38	165	1947	04-26	0	0									
			01-29	71	188	02-29	107	272	03-25	84	274	1948	04-28	25	94									
			01-29	102	274	02-26	132	414	03-29	119	455	1949	05-01	0	0									
			01-29	84	208	02-27	97	284	03-30	130	414	1950	04-30	66	262									
			01-29	117	310	02-27	137	417	03-30	130	488	1951												
			01-28	135	351	02-25	132	394	03-30	119	455	1952	04-27	53	234									
			01-31	107	282	02-26	109	269	03-29	97	346	1953												
			01-29	127	287	02-25	124	373	04-05	109	386	1954												
			01-29	58	147	02-26	99	226	03-30	107	300	1955												
			01-29	145	411	02-26	173	503	03-29	137	498	1956												
			01-27	79	180	02-28	97	254	03-31	109	351	1957												
			01-30	107	279	02-27	109	371	03-27	97	384	1958												
			01-26	112	274	02-24	135	325	03-30	132	444	1959												
			01-28	86	188	02-25	114	251	03-31	81	267	1960												
			01-26	81	211	02-23	122	361	03-30	127	465	1961	04-27	81	320									
			01-30	89	254	02-26	109	302	03-29	124	411	1962	04-28	56	211									
			01-31	48	124	02-28	48	157	03-28	48	147	1963	04-29	15	53									
			01-30	107	287	02-27	97	323	03-30	112	373	1964	04-30	74	302									
			02-01	114	343	03-01	124	391	03-31	112	396	1965	04-30	41	180									
			01-31	104	269	02-28	102	305	03-30	86	297	1966	04-29	41	170									
			01-31	97	295	03-01	104	333	03-31	114	396	1967	05-01	86	335	05-15	46	193	05-31	3	5			
			01-29	89	211	02-28	79	262	03-29	84	307	1968	04-25	76	305									
			01-31	147	389	02-27	163	531	03-28	124	498	1969	04-30	63	317									
			01-30	81	196	03-02	97	272	04-01	84	290	1970	04-30	58	246									
			01-29	104	297	02-26	107	348	03-30	152	483	1971	04-30	84	323									
			01-28	102	295	02-29	107	335	03-27	91	335	1972	04-26	71	333									
			01-30	81	203	02-28	91	290	03-28	97	323	1973	04-27	51	201									
			01-31	127	353	02-27	152	452	03-27	135	478	1974	04-26	102	406	05-13	41	165						
			01-30	102	251	02-26	135	358	03-26	137	389	1975	04-29	91	345	05-15	36	137						
			01-29	86	239	02-26	114	292	03-30	122	356	1976	04-29	86	323	05-14	23	84						
			01-27	36	63	02-28	48	81	03-30	69	173	1977	04-29	10	30	05-15	0	0						
			01-30	104	274	02-28	127	381	03-30	94	325	1978	04-27	56	229									
			01-30	48	89	02-27	93	204	03-27	76	221	1979	04-30	34	132									
			01-31	69	183	02-29	94	275	03-31	105	360	1980	04-29	32	144									
				94	239		109	310		100	338	MEAN		53	214		29	116		3	5			

NO. 2B02A FARRON NO. 2 REGION: COLUMBIA

ELEV. 1220 METRES LAT. 49-16 LONG. 118-08 DRAINAGE: LOWER COLUMBIA

JANUARY 1			FEBRUARY 1			MARCH 1			APRIL 1			YEAR	MAY 1			MAY 15			JUNE 1			JUNE 15		
DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm		DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm	DATE	SNOW DEPTH cm	WATER EQUIVALENT mm
			01-30	84	198	02-28	89	259	03-28	91	292	1973	04-27	51	180									
			01-31	127	328	02-27	147	450	03-27	135	480	1974	04-26	99	406									
			01-30	99	249	02-26	130	351	03-26	137	411	1975	04-29	91	366	05-15	41	173						
			01-29	81	229	02-26	114	277	03-30	124	338	1976	04-29	81	312	05-14	23	79						
			01-27	36	63	02-28	48	79	03-30	71	195	1977	04-29	8	23									
			01-30	112	312	02-28	127	386	03-30	91	343	1978	04-27	63	259									
			01-30	62	184	02-27	104	244	03-27	80	228	1979	04-30	45	174									
			01-31	75	193	02-29	99	304	03-31	114	381	1980	04-29	40	155									
				83	210		107	294		105	333	MEAN		60	234		32	126						

SUTHERLAND CREEK NEAR FIFE
STATION NO. 08NN016
MONTHLY + ANNUAL MEANS, DISCHARGES IN M3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1960	--------	--------	--------	--------	4.01	3.24	0.41	0.13	0.08	--------	--------	--------	--------	1960
1961	--------	--------	--------	--------	--------	--------	0.27	0.09	0.06	--------	--------	--------	--------	1961
1962	--------	--------	--------	--------	2.05	1.40	0.52	0.10	0.08	--------	--------	--------	--------	1962
1963	--------	--------	--------	0.36	1.55	0.82	0.36	0.12	0.09	--------	--------	--------	--------	1963
1964	--------	--------	--------	0.41	2.11	2.03	0.37	0.22	0.15	--------	--------	--------	--------	1964
1965	--------	--------	--------	1.94	3.87	1.78	0.36	0.15	0.07	--------	--------	--------	--------	1965
1966	--------	--------	--------	0.34	1.16	0.48	0.17	0.06	0.04	--------	--------	--------	--------	1966
1967	--------	--------	--------	0.73	3.13	2.57	0.33	0.09	0.07	--------	--------	--------	--------	1967
1968	--------	--------	--------	--------	--------	--------	0.26	0.14	0.11	--------	--------	--------	--------	1968
1969	--------	--------	--------	--------	--------	--------	0.66	0.13	0.09	--------	--------	--------	--------	1969
1970	--------	--------	--------	--------	--------	--------	0.24	0.08	0.06	--------	--------	--------	--------	1970
1973	--------	--------	--------	0.64	2.74	0.92	0.22	0.10	0.10	--------	--------	--------	--------	1973
MEAN	--------	--------	--------	0.74	2.58	1.66	0.35	0.12	0.08	--------	--------	--------	--------	MEAN

Table A2: Sutherland Creek near Fife, discharge data (Water Survey of Canada, 1989)

MOODY CREEK NEAR CHRISTINA
STATION NO. 08NN021
MONTHLY + ANNUAL MEANS, DISCHARGES IN M3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1971	--------	--------	--------	--------	--------	--------	--------	0.03	0.02	0.02	0.03	0.02	--------	1971
1972	0.02	0.01	0.07	0.40	0.63	0.25	0.10	0.03	0.02	0.02	0.02	0.02	0.13	1972
1973	0.01	0.01	0.03	0.18	0.30	0.10	0.03	0.01	0.01	0.02	0.02	0.04	0.06	1973
1974	0.06	0.07	0.10	1.09	1.08	0.23	0.07	0.03	0.01	0.01	0.01	0.02	0.23	1974
1975	0.01	0.01	0.02	0.16	0.70	0.16	0.06	0.03	0.01	0.01	0.02	0.02	0.10	1975
1976	0.02	0.02	0.02	0.35	0.60	0.19	0.09	0.08	0.05	0.03	0.03	0.02	0.12	1976
1977	0.01	0.02	0.02	0.09	0.17	0.11	0.04	0.02	0.01	0.01	0.01	0.02	0.04	1977
1978	0.01	0.02	0.08	0.50	0.49	0.17	0.08	0.04	0.04	0.03	0.03	0.02	0.13	1978
1979	0.01	0.01	0.03	0.22	0.51	0.10	0.05	0.02	0.02	0.01	0.01	0.01	0.08	1979
1980	0.01	0.01	0.03	0.47	0.49	0.17	0.07	0.03	0.02	0.02	0.02	0.02	0.11	1980
1981	0.03	0.04	0.14	0.32	0.48	0.42	0.27	0.10	0.04	0.04	0.04	0.03	0.16	1981
1982	0.03	0.04	0.10	0.34	0.67	0.16	0.10	0.04	0.03	0.03	0.03	0.02	0.13	1982
1983	0.03	0.06	0.50	0.86	0.94	0.29	0.14	0.07	0.03	0.02	0.05	0.05	0.25	1983
1984	0.05	0.06	0.26	0.82	0.90	0.34	0.08	0.03	0.02	0.02	0.02	0.02	0.22	1984
MEAN	0.02	0.03	0.11	0.45	0.61	0.21	0.09	0.04	0.02	0.02	0.02	0.02	0.14	MEAN

Table A3: Moody Creek near Christina Lake, discharge data (Water Survey of Canada, 1989)

Table A4: Big Sheep Creek near Rossland (Water Survey of Canada, 1989)

BIG SHEEP CREEK NEAR ROSSLAND - STATION NO. 08NE038

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

AR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
29	---	---	---	---	---	---	---	---	0.502	0.451	0.484	0.444	---	1929
30	0.348	0.387	0.550	8.05	7.42	5.70	1.57	0.591	0.490	---	---	---	---	1930
49	---	---	---	---	29.0	4.37	1.22	0.613	0.485	0.515	0.535	0.889	---	1949
50	0.849	0.579	0.703	8.08	30.3	18.3	2.40	0.780	0.489	1.48	3.17	4.45	5.98	1950
51	3.79	3.08	3.05	22.3	38.2	10.1	2.16	0.663	0.638	2.70	2.38	3.47	7.82	1951
52	1.73	1.34	1.66	26.3	31.8	8.23	4.05	0.837	0.567	0.464	0.481	0.472	6.53	1952
53	0.575	0.701	1.75	10.2	31.0	22.4	5.23	1.18	0.677	0.723	1.06	1.05	6.42	1953
54	0.946	0.980	2.50	9.81	34.1	13.0	5.17	1.53	2.27	1.82	4.14	3.06	6.85	1954
55	1.65	1.16	0.885	8.51	23.4	24.2	8.14	1.93	0.800	0.670	1.69	1.18	5.98	1955
56	1.01	0.817	1.60	24.7	35.1	13.7	3.67	0.870	0.584	0.851	0.536	0.473	6.69	1956
57	0.349	0.400	0.784	8.36	30.7	8.36	1.78	0.788	0.508	0.572	0.844	0.872	4.36	1957
58	0.818	2.85	5.87	12.6	35.7	9.37	3.26	0.975	0.581	0.858	0.631	0.821	6.14	1958
59	1.41	1.09	1.42	14.7	29.8	19.9	2.71	0.818	1.71	3.31	3.05	2.36	6.87	1959
60	1.70	1.21	5.42	16.6	27.0	18.0	1.88	0.802	0.478	0.483	0.488	0.417	6.03	1960
61	0.484	1.41	3.70	13.6	37.2	14.6	1.34	0.481	0.383	0.384	0.384	0.338	5.21	1961
62	0.283	0.291	0.447	13.0	18.3	11.5	1.85	0.684	0.402	0.745	1.02	2.04	4.30	1962
63	1.65	1.79	2.35	10.0	20.5	6.44	2.04	0.582	0.438	0.412	0.596	0.809	3.87	1963
64	0.886	0.598	0.715	8.17	25.1	18.6	3.29	1.18	0.838	0.780	0.820	0.782	6.21	1964
65	0.882	0.867	2.23	15.5	22.2	9.89	1.85	0.639	0.806	0.509	0.599	0.579	4.87	1965
66	0.536	0.691	1.75	11.6	19.6	7.47	2.14	0.601	0.380	0.361	0.446	1.05	3.90	1966
67	1.04	1.62	2.46	8.07	26.8	21.4	2.27	0.484	0.318	0.438	0.511	0.882	5.62	1967
68	0.789	1.62	6.73	5.54	22.5	13.9	2.05	1.13	1.40	1.65	3.19	2.50	5.28	1968
69	1.37	1.13	2.35	24.3	37.3	11.6	3.83	0.867	0.884	0.858	1.24	1.04	7.22	1969
70	0.752	0.805	1.58	4.54	20.7	9.87	1.87	0.673	0.486	0.482	0.483	0.487	3.58	1970
71	0.609	1.18	1.30	11.6	34.5	15.6	4.46	0.871	0.843	0.554	0.595	0.581	6.08	1971
72	0.598	0.554	5.48	9.58	33.5	15.6	6.36	1.35	0.881	0.813	1.03	0.828	6.38	1972
73	0.815	0.749	2.31	8.50	23.4	8.79	1.80	0.549	0.487	0.758	3.75	4.26	4.68	1973
74	4.87	3.31	3.80	18.3	31.2	28.0	4.82	1.08	0.558	0.488	0.804	0.523	8.30	1974
75	0.615	0.409	0.885	6.86	27.3	18.7	3.81	0.974	0.822	0.700	2.06	2.88	5.84	1975
76	1.83	1.36	1.33	12.2	30.0	14.1	3.87	5.25	3.14	1.09	0.778	0.583	6.31	1976
77	0.523	0.501	0.620	5.44	13.0	8.05	1.24	0.570	0.522	0.580	0.728	0.612	2.56	1977
78	0.815	0.784	5.37	17.1	27.7	15.5	3.59	1.25	1.74	1.48	1.05	0.784	6.45	1978
79	0.468	0.584	1.41	5.89	23.9	6.84	1.75	0.581	0.587	0.592	0.600	0.868	3.89	1979
80	0.589	0.819	2.87	24.8	31.0	8.81	2.84	1.38	1.14	0.823	1.85	2.08	8.81	1980
81	3.89	4.40	5.40	11.4	33.0	18.7	8.20	2.30	0.889	1.44	2.72	2.36	8.16	1981
82	1.33	2.26	4.04	9.30	31.1	15.7	5.03	1.83	1.03	0.954	1.02	0.930	6.85	1982
83	0.975	2.49	11.0	19.3	36.9	18.1	6.84	2.50	0.833	0.883	3.32	2.19	8.84	1983
84	1.88	1.52	5.56	16.1	25.1	29.6	5.86	1.14	0.738	0.681	0.732	0.536	7.46	1984
85	0.492	0.418	0.595	10.0	22.6	8.83	1.37	0.647	0.852	0.668	1.86	0.883	4.13	1985
86	0.831	0.852	5.95	13.4	16.8	6.88	2.29	0.862	0.890	0.982	1.02	1.01	6.40	1986
EAN	1.14	1.24	2.89	13.7	27.7	13.6	3.37	1.09	0.812	0.888	1.33	1.31	5.83	MEAN

LOCATION - LAT 49 01 00 N DRAINAGE AREA, 347 km²
LONG 117 56 40 W NATURAL FLOW

CHRISTINA CREEK AT OUTLET OF CHRISTINA LAKE
STATION NO. 08NN014
MONTHLY + ANNUAL MEANS, DISCHARGES IN M3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1944	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1.01	1.36	--------	1944
1945	1.59	1.85	2.09	6.17	33.5	23.0	5.58	1.51	0.56	0.41	0.94	1.42	6.58	1945
1946	2.03	1.85	2.54	14.7	40.4	16.8	5.85	1.62	0.78	--------	--------	--------	--------	1946
MEAN	1.81	1.85	2.32	10.4	37.0	19.9	5.72	1.57	0.67	0.41	0.97	1.39	6.58	MEAN

Table A5:Christina Creek at the outlet of Christina Lake, discharge data (Water Survey of Canada, 1989)

TABLE A6 CHRISTINA LAKE AND TRIBUTARIES WATER LICENCE DATA

SOURCE	USE							
	WATERWORKS		DOMESTIC		INDUSTRIAL		IRRIGATION	
	cfs	# of licences	cfs	# of licences	cfs	# of licences	cfs	# of licences
ANN SPR.	0	0	0.002	2	0.000	0	0.000	0
AQUARIUS BR.	0	0	0.000	0	0.000	0	0.202	1
BAKER CR.	0.004	1	0.000	0	0.000	0	0.000	0
BART CR.	0	0	0.001	1	0.000	0	0.000	0
BROOKS CR.	0	0	0.004	1	0.000	0	0.000	0
CHRISTINA LK.	0.291	3	0.035	6	0.089	1	0.000	0
COPPER CR.	0	0	0.003	2	0.000	0	0.126	1
CORYELL CR.	0	0	0.001	1	0.000	0	0.000	0
DYSON SPR.	0	0	0.007	7	0.000	0	0.000	0
EARHART CR.	0	0	0.002	2	0.000	0	0.000	0
FERRARO SPR.	0	0	0.001	1	0.000	0	0.000	0
GILL CR.	0	0	0.009	6	0.000	0	0.000	0
HOFER CR.	0	0	0.001	1	0.000	0	0.000	0
ITALY CR.	0	0	0.001	1	0.000	0	0.000	0
LIGHTHOUSE CR.	0	0	0.001	1	0.000	0	0.000	0
MAIDA CR.	0	0	0.001	1	0.000	0	0.101	1
MAIDA SPR.	0	0	0.002	1	0.000	0	0.051	1
MCRAE CR.	0	0	0.005	3	0.005	1	0.253	1
MURPHY SPR.	0	0	0.002	1	0.000	0	0.000	0
PALMA SPR.	0	0	0.003	1	0.000	0	0.000	0
PARSON CR.	0	0	0.002	2	0.000	0	0.000	0
ROBINSON SPR.	0	0	0.002	1	0.000	0	0.000	0
SPOONER CR.	0	0	0.005	3	0.000	0	0.000	0
STEPKINSON BR.	0	0	0.006	5	0.000	0	0.000	0
STEWART CR.	0	0	0.013	13	0.000	0	0.000	0
SUTHERLAND CR.	0.6	2	0.019	18	0.000	0	0.857	13
SUTHERLAND CR. S. OUTLET	0	0	0.056	50	0.001	1	0.133	2
SWETLAND SPRS.	0	0	0.002	1	0.000	0	0.202	1
SZIMMER SLOUGH	0	0	0.000	0	0.000	0	0.212	1
TEXAS CR.	0	0	0.006	3	0.000	0	0.000	0
TREADMILL CR.	0	0	0.001	1	0.000	0	0.000	0
WALKER CR.	0	0	0.001	1	0.000	0	0.000	0
WOODLEY CR.	0	0	0.003	3	0.000	0	0.000	0
TOTAL	0.895	6	0.197	140	0.095	3	2.136	22

Table A7: Chlorophyll a Concentrations in Christina Lake, October 1980 to October 1990

Date	Station 0200078			Station 0200520		
	Upper Depth metres	Lower Depth metres	Chlorophyll a mg/m3	Upper Depth metres	Lower Depth metres	Chlorophyll a mg/m3
80/10/01	2	6	0.6	2	6	0.7
81/04/28	2	6	0.6	2	6	0.9
83/03/16	0	10	1.8	0	10	1.7
83/09/21	0	10	0.6			
84/04/17	0	10	0.9	0	10	0.8
84/10/02	0	10	0.8	0	10	0.7
86/04/16	0	0	1.3	0	10	1.8
86/09/30	0	10	0.6	0	10	0.7
88/04/14	0	10	< 0.5	0	10	1.5
88/09/29	0	10	0.6	0	10	0.7
90/03/22	1	10	4.6	1	10	4.8
90/10/11	0	10	1.3	0	10	1.5
	Maximum = 4.6 Minimum = < 0.5 Mean = 1.2 Summer/Fall Mean = 0.8			Maximum = 4.8 Minimum = 0.7 Mean = 1.4 Summer/Fall Mean = 0.9		

Note: This table was created with machine read SEAM data from diskette

Table A8: **Christina Lake Phytoplankton Summary, October 1980 to October 1990**

D = Dominant Organisms (> 10 %)
ND = Non Dominant Organisms (usually identified to genus only)

Date	80/10/01	80/10/01	80/10/01	81/04/28	81/04/28	81/04/28	86/04/16	90/03/22	90/03/22	90/10/11	90/10/11
Sampling Station	0200078	0200520	0200519	0200078	0200520	0200519	0200078	0200078	0200520	0200078	0200520
Taxonomic Identification											
Order: Centrales											
Cyclotella	ND			ND	ND	ND		ND	ND	ND	ND
Cyclotella glomerata							D				
Cyclotella kutzingiana		D	D								
Melosira	ND	ND	ND	ND			ND				
Melosira italica								ND	D	D	ND
Stephanodiscus				ND			D				
Order: Chlorococcales											
Ankistrodesmus	ND			ND	ND	ND	ND				
Ankistrodesmus falcatus								ND	ND	ND	ND
Botryococcus		ND			ND	ND					
Crucigenia	ND	ND	ND								
Crucigenia rectangularis								ND		ND	ND
Elakotothrix gelatinosa									ND		
Oocystis				ND			ND			ND	ND
Nephrocytium	ND	ND		ND	ND						
Pediastrum tetras									ND	ND	
Schroderia	ND			ND		ND					
Scenedesmus quadricauda											ND
Selenastrum minutum								ND			
Sphaerocystis schroeteri									ND	ND	ND
Order: Chroococcales											
Aphanocapsa				ND							
Chroococcus				ND	ND	ND					
Gomphosphaeria lacustris			D								
Merismopedia					ND						
Order: Chrysomonadales (same as Ochromonadales?)											
Dinobryon	ND	ND	ND	ND	ND	ND					
Dinobryon cylindricum	D	D	D								
Epipyxis				ND	ND	ND					
Order: Cryptomonadales											
Chroomonas	ND	ND	ND	ND	ND	ND	ND				
Chroomonas acuta								D	ND	D	D
Cryptomonas			ND	ND	ND	ND					
Cryptomonas marsonii									ND	ND	
Cryptomonas ovata								ND	ND		ND
Order: Desmidiales											
Cosmarium				ND	ND						
Spondylosium	ND	ND	ND	ND	ND	ND					
Staurastrum	ND		ND	ND	ND	ND					
Order: Dinokontae											
Dinoflagellate								ND	ND		
Order: Euglenales											
Euglena								ND			
Trachelomonas	ND			ND	ND						
Order: Monosigales											
Stelexomonas				ND	ND						
Order: Nostocales											
Anabaena affinis											
Anabaena										ND	

Table A8, continued: Christina Lake Phytoplankton Summary, October 1980 to October 1990

D = Dominant Organisms (> 10 %)
ND = Non Dominant Organisms (usually identified to genus only)

Date Sampling Station	80/10/01 0200078	80/10/01 0200520	80/10/01 0200519	81/04/28 0200078	81/04/28 0200520	81/04/28 0200519	86/04/16 0200078	90/03/22 0200078	90/03/22 0200520	90/10/11 0200078	90/10/11 0200520
Taxonomic Identification											
Order: Ochromonadales											
Dinobryon divergens								ND	ND	ND	ND
Order: Oscillatoriales											
Anabaena				ND			D				
Lyngybe subtilis								D	D		D
Oscillatoria				ND	ND	ND					
Order: Pennales											
Achnanthes	ND			ND	ND	ND					
Amphipleura		ND									
Amphora ovalis										ND	
Asterionella	ND	ND	ND				ND				
Asterionella formosa				D	D	D		ND	D		D
Cocconeis		ND	ND	ND	ND						
Cocconeis placentula								ND		ND	
Cymbella	ND	ND	ND		ND						
Diatoma		ND			ND						
Fragilaria	ND	ND	ND	ND	ND	ND	ND			ND	
Gomphonema	ND		ND		ND						
Hannaea					ND	ND					
Meridion				ND	ND						
Navicula	ND	ND	ND	ND	ND	ND	ND	ND		ND	
Nitzschia		ND			ND	ND	ND				
Nitzschia dissipata										ND	
Pleurosigma delicatulum										ND	
Rhizosolenia			ND	ND	ND						
Rhizosolenia eriensis	D	D				D					
Rhopalodia				ND							
Surirella					ND						
Synedra				ND			ND				
Synedra acus								ND	ND		
Synedra ulna								ND	ND		ND
Tabellaria		ND		ND							
Tabellaria fenestrata								ND	ND		
Order Peridiniales	ND		ND	ND		ND					
Ceratium	ND	ND			ND						
Order: Rhizochrysidales											
Diceras	ND	ND	ND								
Deceras phaeolus										ND	ND
Order: Tetrasporales											
Elakatothrix			ND	ND	ND		ND				
Elakatothrix gelatinosa	D	D									
Gloeocystis	ND				ND						
Stylosphaeridi	ND										
Tetraspora							ND				
Order: Volvocales											
Carteria				ND							
Eudorina elegans	D	D	D								
Order: Zygnematales											
Spondylosium sp.									ND		
Mougeotia	ND	ND	ND		ND						

Table A9: Christina Lake Zooplankton Summary, October 1980 to March 1990

D = Dominant Organisms (> 10 %)
ND = Non Dominant Organisms (usually identified to genus only)

Date Sampling Station	80/10/01 0200078	80/10/01 0200520	83/03/16 0200078	83/03/16 0200520	86/04/16 0200078	86/04/16 0200520	90/03/22 0200078	90/03/22 0200520
Taxonomic Identification								
Order: Cladocera								
Bosmina longirostris	D	D					D	D
Bosmina sp	ND				ND	ND		
Holopedium gibberum	D	D						
Order: Calanoida								
Diaptomus			ND	ND	ND	ND	ND	D
Epischura nevadensis	D	D						
Order: Cyclopodia								
Cyclops bicuspidata	D	D						ND
Cyclops sp	ND	ND	ND	ND				
Sub-class: Copepoda								
Nauplii	ND	ND	ND	ND	D	D	ND	ND
Rotifers:								
Keratella					ND	ND	ND	ND
Family: Conochilidae	ND	ND			D			
Family: Brachionidae								
Kellicottia longispina	D	D	D	D	D	D		

Table A10: Total Phosphorus Concentrations 1980 - 1990

Date	Station 0200078					
	Epilimnion			Hypolimnion		
	Upper Depth metres	Lower Depth metres	Total P mg/L	Upper Depth metres	Lower Depth metres	Total P mg/L
80/10/01	2	6	0.007	20	20	0.013
81/04/28	2	6	0.008	20	20	0.008
81/09/02				20	20	0.016
83/03/16	0	10	0.009	20	20	0.01
83/09/21	0	10	0.012	20	20	0.01
84/04/17	0	10	0.009	20	20	0.012
86/04/16	0	10	0.008	20	20	0.008
86/09/30	0	10	0.004	20	20	0.005
88/04/14	0	10	0.006	20	20	0.009
88/09/29	0	10	0.003	20	20	0.005
90/03/22	1	10	0.003	20	20	0.003
90/10/11	0	10	0.004			
	Station 0200520					
80/10/01	2	6	0.007	20	32	0.009
81/04/28	2	6	0.008	20	32	0.008
81/09/02	2	6	0.007	20	32	0.008
83/03/16	0	10	0.009	20	32	0.009
83/09/21				20	32	0.009
84/04/17	0	10	0.011	20	32	0.023
84/10/02	0	10	0.008	20	32	
86/04/16	0	10	0.009	20	32	0.009
86/09/30	0	10	0.004	20	32	0.005
88/04/14	0	10	0.006	20	32	0.004
88/09/29	0	10	0.003	20	32	0.004
90/03/22	1	10	0.003	20	32	0.003
90/10/11	0	10	0.004	20	34	0.004

Note: The lake was unstratified or just beginning to stratify in March and April therefore these samples are not truly epilimnetic and hypolimnetic.

This table was created with machine read SEAM data from diskette

Table A11: Total Dissolved Phosphorus Concentrations 1980 - 1990

Date	Station 0200078					
	Epilimnion			Hypolimnion		
	Upper Depth metres	Lower Depth metres	Total Diss P mg/L	Upper Depth metres	Lower Depth metres	Total Diss P mg/L
80/10/01	2	6	0.003	20	20	0.005
81/04/28	2	6	0.005	20	20	0.006
81/09/02				20	20	0.008
83/03/16	0	10	0.005	20	20	0.005
83/09/21	0	10	0.006	20	20	0.007
84/04/17	0	10	0.005	20	20	0.005
86/04/16	0	10	0.003	20	20	0.003
86/09/30	0	10	<0.003	20	20	<0.003
88/04/14	0	10	0.003	20	20	0.004
88/09/29	0	10	<0.003	20	20	<0.003
90/03/22	1	10	<0.003	20	20	<0.003
90/10/11	0	10	<0.003			
	Station 0200520					
80/10/01	2	6	0.003	20	32	0.003
81/04/28	2	6	0.005	20	32	0.005
81/09/02	2	6	0.005	20	32	0.007
83/03/16	0	10	0.005	20	32	0.006
83/09/21				20	32	0.005
84/04/17	0	10	0.003	20	32	0.003
84/10/02	0	10	0.005	20	32	
86/04/16	0	10	0.003	20	32	0.003
86/09/30	0	10	<0.003	20	32	0.003
88/04/14	0	10	0.003	20	32	<0.003
88/09/29	0	10	<0.003	20	32	<0.003
90/03/22	1	10	<0.003	20	32	<0.003
90/10/11	0	10	<0.003	20	34	<0.003

Note: The lake was unstratified or just beginning to stratify in March and April therefore these samples are not truly epilimnetic and hypolimnetic.

This table was created with machine read SEAM data from diskette

Table A12: Ortho Dissolved Phosphorus (Values only Taken Until 1978)

Note: Samples were taken at discrete depths

Station 0200078		
Date	Depth metres	Ortho Diss P mg/L
72/07/17	0.9	<0.003
72/08/21	0.9	<0.003
72/08/21	7.6	0.003
72/08/21	18.3	<0.003
73/05/24	0.3	0.006
73/08/14	0.9	<0.003
73/08/14	10.7	<0.003
73/08/14	23.2	<0.003
73/11/07	0.9	<0.003
73/11/07	10.4	<0.003
73/11/07	18.9	<0.003
75/06/10	1	<0.003
75/06/10	23	<0.003
75/07/15	1	<0.003
75/07/15	19	<0.003
75/08/19	1	<0.003
75/08/19	20	<0.003
76/06/15	1	<0.003
76/06/15	24	<0.003
76/07/21	1	<0.003
76/07/21	21	<0.003
76/09/27	1	<0.003
76/09/27	21	<0.003
77/07/20	1	<0.003
77/07/20	21	<0.003
77/09/20	0	<0.003
77/09/20	23	<0.003
78/04/04	1	<0.003
78/04/04	13	<0.003
78/07/18	1	<0.003
78/07/18	19	<0.003
78/08/22	1	<0.003
78/08/22	21	<0.003

Station 0200520		
Date	Depth metres	Ortho Diss P mg/L
76/06/16	1	<0.003
76/06/16	32	<0.003
76/07/20	32	<0.003
76/07/20	1	<0.003
76/09/27	36	<0.003
76/09/27	1	<0.003
77/07/19	31.1	<0.003
77/07/19	1	<0.003
77/09/20	32.9	<0.003
77/09/20	0	<0.003
78/04/04	1	<0.003
78/04/04	32	<0.003
78/07/18	36.9	<0.003
78/07/18	1	<0.003
78/08/22	1	<0.003
78/08/22	36	<0.003

Note: This table was created with machine read SEAM data on diskette

Table A13: Nitrogen Concentrations - Station 0200078

			Epilimnion						Hypolimnion			
			TKN	Ammonia NH3	Organic Nitrogen	NO2 & NO3			TKN	Ammonia NH3	Organic Nitrogen	NO2 & NO3
Date	Upper Depth (m)	Lower Depth (m)	mg/L	mg/L	mg/L	mg/L	Upper Depth (m)	Lower Depth (m)	mg/L	mg/L	mg/L	mg/L
75/06/10	1	1	0.08	0.006	0.074		23	23	0.05	0.006	0.044	
75/07/15	1	1	0.07	<0.005	0.07		19	19	0.08	<0.005	0.08	
75/08/19	1	1	0.03	0.006	0.024		20	20	0.02	0.009	0.011	
76/06/15	1	1	0.18	<0.005	0.18	0.02	24	24	0.07	0.005	0.065	<0.02
76/07/21	1	1	0.09	0.005	0.085	<0.02	21	21	0.09	0.005	0.085	<0.02
76/09/27	1	1	0.13	0.005	0.125	<0.02	21	21	0.26	0.005	0.255	<0.02
77/07/20	1	1	0.08	<0.005	0.08	<0.02	21	21	0.08	<0.005	0.08	<0.02
77/09/20	0	0	0.01	0.007	0.003	<0.02	23	23	0.05	0.009	0.041	<0.02
78/04/04	1	1	0.08	0.008	0.072	0.08	13	13	0.11	0.008	0.102	0.08
78/07/18	1	1	0.06	<0.005	0.06	<0.02	19	19	0.18	<0.005	0.18	<0.02
78/08/22	1	1	0.06	0.005	0.055	<0.02	21	21	0.06	<0.005	0.06	<0.02
80/10/01	2	6	0.15	0.01	0.14	<0.02	20	20	0.14	0.014	0.126	<0.02
81/04/28	2	6	0.04	0.015	0.025	<0.02	20	20	0.07	0.016	0.054	<0.02
81/09/02							20	20	0.17	<0.005	0.17	<0.02
83/03/16	0	10	0.1	<0.005	0.1	<0.02	20	20	0.18	<0.005	0.18	<0.02
83/09/21	0	10	0.08	<0.005	0.08	<0.02	20	20	0.08	<0.005	0.08	<0.02
84/04/17	0	10	0.1	<0.005	0.1	<0.02	20	20	0.14	<0.005	0.14	<0.02
84/10/02	0	10	0.12	<0.005	0.12	<0.02	20	20	0.08	<0.005	0.08	<0.02
86/04/16	0	10	0.06	<0.005	0.06	<0.02	20	20	0.08	<0.005	0.08	<0.02
88/04/14	0	10	0.11	<0.005	0.11	0.02	20	20	0.1	<0.005	0.1	0.04
88/09/29	0	10	0.09	<0.005	0.09	<0.02	20	20	0.1	<0.005	0.1	<0.02
90/03/22	1	10	0.11	<0.005	0.11	<0.02	20	20	0.07	<0.005	0.07	<0.02
90/10/11	0	10	0.07	<0.005	0.07	<0.02	20	24	0.06	<0.005	0.06	<0.02

Note: This table was created with machine read SEAM data from diskette

Table A14: Nitrogen Concentrations - Station 0200520

			Epilimnion						Hypolimnion			
			TKN	Ammonia NH3	Organic Nitrogen	NO2 & NO3			TKN	Ammonia NH3	Organic Nitrogen	NO2 & NO3
Date	Upper Depth (m)	Lower Depth (m)	mg/L	mg/L	mg/L	mg/L	Upper Depth (m)	Lower Depth (m)	mg/L	mg/L	mg/L	mg/L
76/06/16	1	1	0.1	0.007	0.093	<0.02	32	32	0.03	0.009	0.021	<0.02
76/07/20	1	1	0.09	0.005	0.085	<0.02	32	32	0.06	0.005	0.055	0.02
76/09/27	1	1	0.12	<0.005	0.12	<0.02	36	36	0.19	<0.005	0.19	0.02
77/07/19	1	1	0.06	<0.005	0.06	<0.02	31.1	31.1	0.08	<0.005	0.08	<0.02
77/09/20	0	0	0.05	0.007	0.043	<0.02	32.9	32.9	0.1	0.007	0.093	<0.02
78/04/04	1	1	0.13	0.008	0.122	0.07	32	32	0.1	0.009	0.091	0.07
78/07/18	1	1	0.06	<0.005	0.06	<0.02	36.9	36.9	0.09	0.006	0.084	<0.02
78/08/22	1	1	0.14	<0.005	0.14	<0.02	36	36	0.2	<0.005	0.2	<0.02
80/10/01	2	6	0.12	0.009	0.111	<0.02	20	32	0.12	0.013	0.107	<0.02
81/04/28	2	6	0.09	0.017	0.073	<0.02	20	32	0.08	0.015	0.065	<0.02
81/09/02	2	6	0.14	<0.005	0.14	<0.02	20	32	0.14	<0.005	0.14	<0.02
83/03/16	0	10	0.12	<0.005	0.12	<0.02	20	32	0.1	0.013	0.087	0.04
83/09/21							20	32	0.06	<0.005	0.06	<0.02
84/04/17	0	10	0.08	<0.005	0.08	<0.02	20	32	0.15	<0.005	0.15	<0.02
84/10/02	0	10	0.11	<0.005	0.11	<0.02	20	32	0.14	<0.005	0.14	<0.02
86/04/16	0	10	0.07	<0.005	0.07	<0.02	20	32	0.07	<0.005	0.07	<0.02
88/04/14	0	10	0.08	<0.005	0.08	<0.02	20	32	0.06	<0.005	0.06	<0.02
88/09/29	0	10	0.11	<0.005	0.11	<0.02	20	32	0.16	<0.005	0.16	<0.02
90/03/22	1	10	0.1	<0.005	0.1	<0.02	20	32	0.08	<0.005	0.08	<0.02
90/10/11	0	10	0.07	<0.005	0.07	<0.02	20	34	0.06	<0.005	0.06	0.02

Table A15 - Christina Lake pH and Alkalinity Station Averages

Date	pH - Lab Values		Alkalinity - 8.3		Alkalinity - 4.5	
	Sta 0200078	Sta 0200520	Sta 0200078	Sta 0200520	Sta 0200078	Sta 0200520
72/07/17	7.5				27.5	
72/08/21	7.5				30.3	
73/05/24					31.0	
73/08/14	7.6				34.2	
73/11/07					33.3	
75/06/10	7.5				30.5	
75/07/15	7.5				30.9	
75/08/19	7.4				29.7	
76/06/15	7.6				31.7	
76/06/16		7.5				31.0
76/07/20		7.8				30.8
76/07/21	7.8				30.7	
76/09/27	7.7	7.6			30.9	30.6
77/07/19		7.7				
77/07/20	7.8					
77/09/20	7.6	7.7				
78/04/04	7.7	7.3			32.9	33.4
78/07/18	7.6	7.6			31.7	31.6
78/08/22	7.5	7.5				
80/10/01	7.7	7.6				
81/04/28	7.6	7.6				
81/09/02	7.8	7.9	<0.5	<0.5	32.8	33.3
83/03/16	7.6	7.6			32.9	32.6
83/09/21	7.6	7.4				
84/04/17	7.7	7.6			32.8	32.9
84/10/02	7.7	7.6				
86/04/16	7.5	7.5	<0.5	<0.5	32.6	
86/09/30	7.5	7.6				
88/04/14	7.5	7.4	<0.5	<0.5	33.0	
88/09/29	7.8	7.8				
90/03/22	7.4	7.5	<0.5	<0.5	32.5	33.7
90/10/11	7.4	7.3	<0.5	<0.5	33.3	33.3

Table A16: Ministry of Health Beach Sampling Fecal Coliform Data

Date	Location	Fecal Coliforms MPN/100 ml
82/06/08	Schullis Resort	9
82/06/08	Schullis Resort	23
82/06/08	Alpine Resort	4
82/06/08	Christina L Prov Park	4
82/06/13	Alpine Resort	23
82/06/14	Christina L Prov Park	9
82/06/21	Schullis Resort	4
82/06/21	Christina L Prov Park	23
82/06/21	Alpine Resort	23
82/06/28	Alpine Resort	23
82/06/29	Skand's Resort	4
82/07/05	Alpine Resort	<3
82/07/05	Schullis Resort	93
82/07/05	Skand's Resort	43
82/07/12	Alpine Resort	4
82/07/12	Christina L Prov Park	4
82/07/19	Alpine Resort	<3
82/07/19	Skand's Resort	4
82/07/25	Alpine Resort	<3
82/07/29	Skand's Resort	<3
82/07/29	Christina L Prov Park	4
82/08/16	Alpine Resort	4
82/08/16	Skand's Resort	<3
82/08/16	Christina L Prov Park	<3
82/08/23	Christina L Prov Park	<3
82/08/23	Alpine Resort	9
82/08/30	Christina L Prov Park	240
82/08/30	Alpine Resort	<3
86/06/04	Christina L Prov Park	93
86/06/04	Schullis Resort	3
86/06/04	Alpine Resort	150
86/06/04	Skand's Resort	7
86/06/17	Alpine Resort	<3
86/06/17	Schullis Resort	4
86/06/17	Skand's Resort	<3
86/06/17	Christina L Prov Park	7
86/07/02	Christina L Prov Park	<3
86/07/02	Skand's Resort	<3
86/07/02	Alpine Resort	<3
86/07/02	Schullis Resort	93
86/07/15	Christina L Prov Park	<3
86/07/15	Alpine Resort	<3
86/07/15	Schullis Resort	4
86/07/15	Skand's Resort	<3
86/07/29	Skand's Resort	9
86/07/29	Alpine Resort	<3
86/07/29	Schullis Resort	<3
86/07/29	Christina L Prov Park	9
86/08/12	Skand's Resort	<3
86/08/12	Schullis Resort	<3
86/08/12	Christina L Prov Park	<3
86/08/12	Alpine Resort	<3
86/08/26	Christina L Prov Park	<3
86/08/26	Skand's Resort	<3
86/08/26	Alpine Resort	<3
86/08/26	Schullis Resort	<3

Continued on next page

Table A16: Ministry of Health Beach Sampling Fecal Coliform Data

Date	Location	Fecal Coliforms Units per 100ml
88/06/14	Skand's Resort	<1
88/06/14	Alpine Resort	<1
88/07/12	Alpine Resort	1
88/07/12	Skand's Resort	<1
88/07/12	Schullis Resort	1
88/07/12	Alpine Resort	1
88/07/18	Starchack Campground	<1
88/07/18	Treadmill C MOF Campground	<1
88/07/18	Parson C MOF Campground	1
88/07/20	Christina L Prov Park	8
89/06/06	Skand's Resort	<5
89/06/06	Schullis Resort	<5
89/06/06	Alpine Resort	<5
89/06/06	Christina L Prov Park	5
89/06/20	Christina L Prov Park	10
89/06/20	Alpine Resort	<5
89/06/20	Skand's Resort	<5
89/06/20	Schullis Resort	<5
89/07/04	Skand's Resort	<5
89/07/04	Christina L Prov Park	<5
89/07/04	Schullis Resort	<5
89/07/04	Alpine Resort	<5
89/07/18	Skand's Resort	5
89/07/18	Schullis Resort	<5
89/07/18	Alpine Resort	<5
89/07/25	Schullis Resort	<5
89/07/25	Alpine Resort	5
89/07/25	Christina L Prov Park	10
89/07/25	Skand's Resort	<5
89/08/08	Alpine Resort	<5
89/08/08	Christina L Prov Park	10
89/08/08	Skand's Resort	<5
89/08/08	Schullis Resort	<5
89/08/15	Schullis Resort	<5
89/08/15	Alpine Resort	5
89/08/15	Christina L Prov Park	<5
89/08/15	Skand's Resort	<5
89/08/25	Skand's Resort	<5
89/08/29	Alpine Resort	<5
89/08/29	Christina L Prov Park	<5
89/08/29	Schullis Resort	<5
90/06/04	Christina L Prov Park	20
90/06/05	Skand's Resort	<5
90/06/12	Christina L Prov Park	<5
90/06/12	Alpine Resort	<5
90/06/12	Schullis Resort	<5
90/06/12	Skand's Resort	<5
90/06/19	Schullis Resort	2.2
90/06/19	Skand's Resort	<5
90/06/19	Alpine Resort	5
90/06/19	Christina L Prov Park	5

Continued on Next Page

Table A16: Ministry of Health Beach Sampling Fecal Coliform Data

Date	Location	Fecal Coliforms Units per 100ml
90/06/26	Christina L Prov Park	1
90/06/26	Schullis Resort	<1
90/06/26	Skand's Resort	<1
90/07/02	Schullis Resort	2
90/07/09	Skand's Resort	1
90/07/09	Christina L Prov Park	2
90/07/10	Skand's Resort	1
90/07/10	Christina L Prov Park	3
90/07/10	Schullis Resort	2
90/07/10	Alpine Resort	<1
90/07/17	Alpine Resort	2
90/07/24	Alpine Resort	<1
90/07/24	Schullis Resort	<1
90/07/24	Skand's Resort	<1
90/07/24	Christina L Prov Park	5
90/08/14	Alpine Resort	6
90/08/21	Christina L Prov Park	2
90/08/21	Alpine Resort	<1
90/08/21	Schullis Resort	<1
90/08/28	Christina L Prov Park	8
90/08/28	Skand's Resort	2
90/08/28	Alpine Resort	<1
90/08/28	Schullis Resort	1

Note: This data was summarized from records from the Central Kootenay Health Unit in Grand Forks

The number of fecal coliforms per 100 ml was determined by the membrane filtration technique. The Guidelines for Canadian Recreation Water Quality (1983) state that the geometric means of not less than 5 samples taken over a 30-day period should be less than 200 fecal coliforms/100 ml.

Table A17: Christina Lake Coliform Data from SEAM

Date	Fecal Coliforms - Membrane Filter Method CFU/cL	
	Station 0200078	Station 0200520
80/10/01	<2	<2
81/04/28	<2	<2
81/09/02	<2	<2
83/03/16	<2	<2
83/09/21	<2	<2
84/10/02	<2	<2
88/04/14	<2	<2
90/03/22	<2	<2
90/10/11	<2	<2

Table A18: 1982 Sutherland Creek Sampling Results

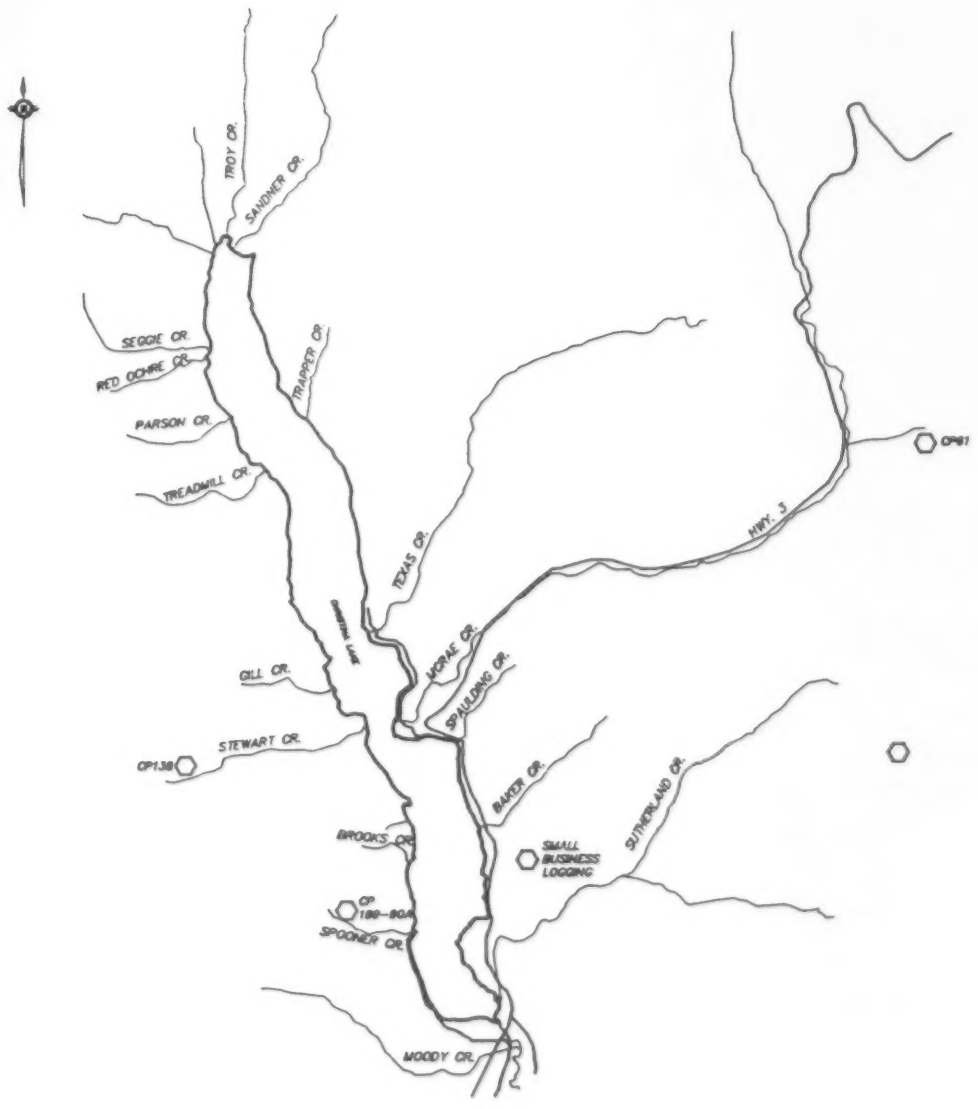
Sampling Date: 82/11/09

Parameter	Unit	Value
Nitrogen Forms:		
Nitrogen, Total	mg/L	0.03
Nitrogen, Organic	mg/L	0.03
Nitrate, Total	mg/L	< 0.02
Nitrite, Dissolved	mg/L	< 0.005
Dissolved Ammonia	mg/L	< 0.005
Nitrite/Nitrate	mg/L	< 0.02
Total Kjeldahl Nitrogen	mg/L	0.03
Total Dissolved Phosphorus	mg/L	0.029
Dissolved Phosphorus	mg/L	0.029
pH, Field Measurement	pH unit	7.3
pH, Lab Measurement	pH unit	7.9
Turbidity	NTU	0.7
Specific Conductance	uS/cm	141

Table A19: Parson and Treadmill Creeks, Ministry of Health sampling results

WATER QUALITY RESULTS Oct. 5, 1988

Parameter	Results (mg/l unless specified) Parson	Treadmill	Max Acceptable
Color True (Col.Units)	15	5	15
pH	7.5	8	
Residue Total	66	106	
Specific Conductance (uS/cm)	76	159	
Alkalinity Total 4.5	32.6	75.2	
Hardness Total	32.8		200
Sulfate Dissolved	5	5.1	500
Calcium	9.04		
Iron	0.43		0.3
Magnesium	2.48		
Manganese	0.01		0.05
Molybenum	0.01		
Lead	<0.1		0.05
Vanadium	<0.01		
Zinc	0.01		
Potassium Diss.	1.4	2.5	
Nitrogen Organic-Tot	0.08	0.04	
Nitrogen Kjel.Tot(N)	0.08	0.04	
Nitrogen NO3+NO2 Dis	<0.02	<0.02	10
Phosphorus Ort. Dis-P	0.004	0.003	
Phosphorus Total	0.009	0.007	
Phosphorus Total Diss	0.007	0.006	
Carbon Tot Organic	2	1	
Carbon Tot Inorganic	9	19	
Carbon Total	11	19	
Sodium Dissolved	3.3	1	



CUTTING PERMIT NO.	YEAR LOGGING PLANNED	AREA TO BE LOGGED ha	LENGTH OF ROAD TO BE BUILT km
61	1994	57	5
138	1991	18	1
199-90A	1990	5	1

LEGEND

FUTURE LOGGING SITE

CHRISTINA LAKE FORESTRY MAP

Figure A1: Proposed logging activity

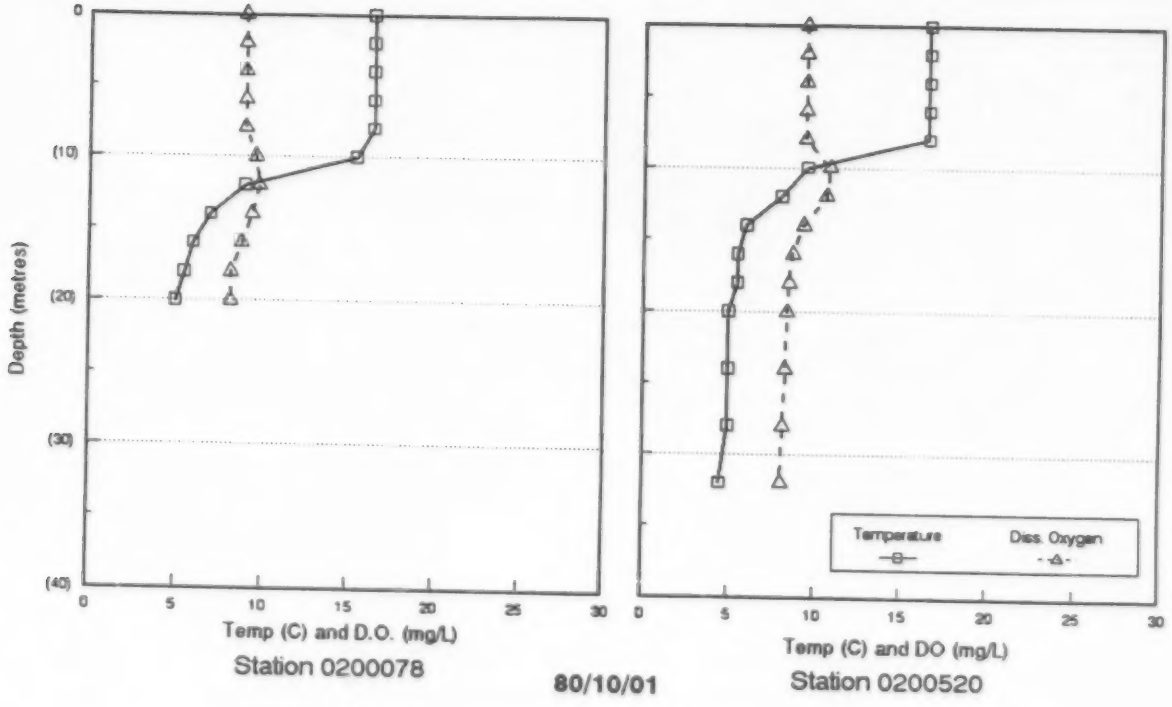


Figure A2: 1980 Christina Lake Temperature and Dissolved Oxygen Profiles

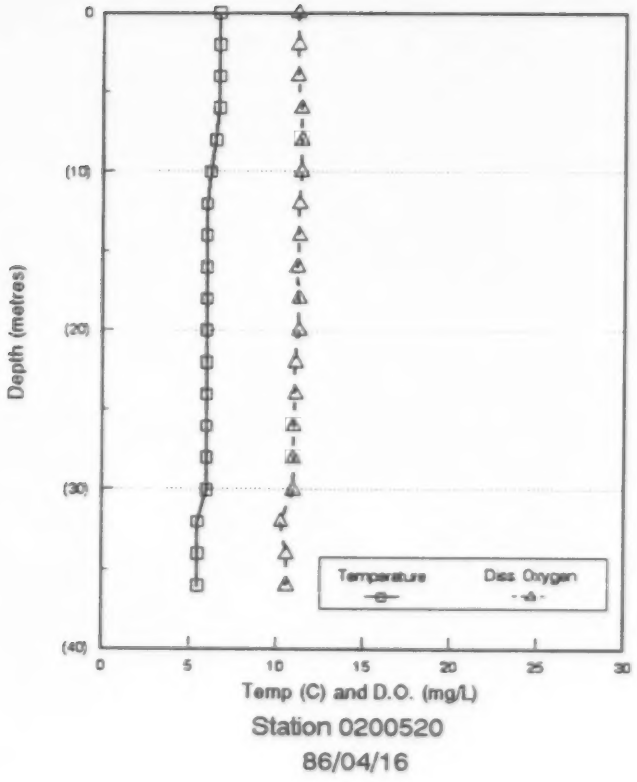


Figure A3: 1986 Christina Lake Temperature and Dissolved Oxygen Profile

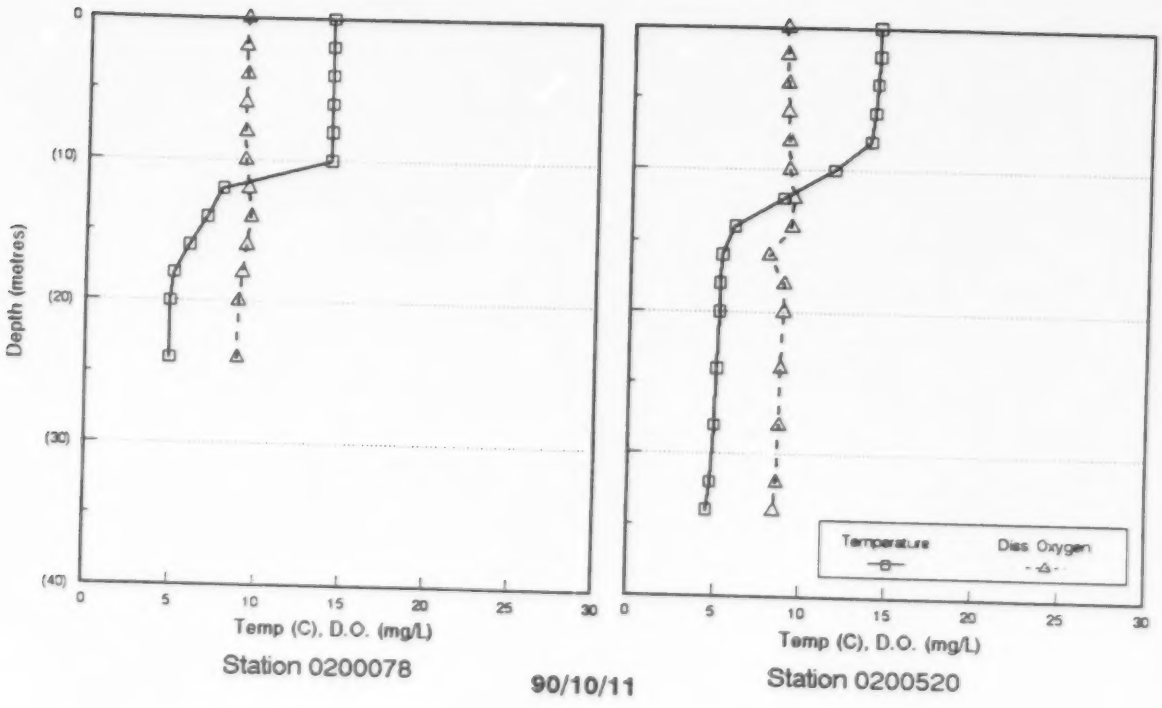
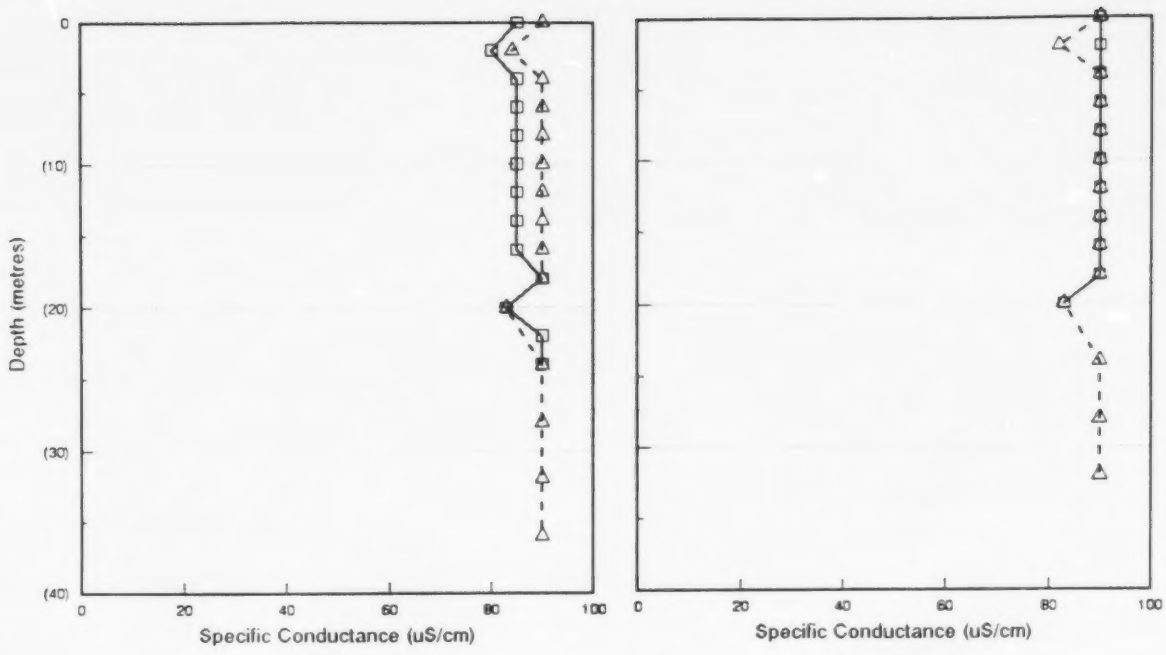


Figure A4: 1990 Christina Lake Temperature and Dissolved Oxygen Profiles



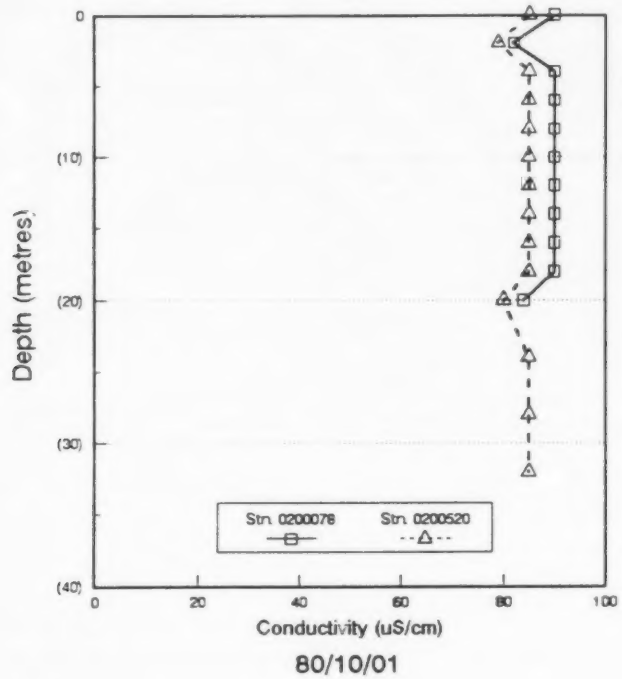


Figure A5: Christina Lake Conductivity Profiles

APPENDIX B

WATER LICENCE DATA

SOURCE	LICENCE#	00 WATERWORKS		01 DOMESTIC		02 INDUSTRIAL		03 IRRIGATION	
		cfs	# of licences	cfs	# of licences	cfs	# of licences	cfs	# of licences
ANN SPR.	F39826			0.001	1				
ANN SPR.	F39827			0.001	1				
AQUARIUS BR.	C40756							0.2020202	1
BAKER CR.	C22856	0.004	1						
BART CR.	C47158			0.001	1				
BROOKS CR.	?			0.004	1				
CHRISTINA LK.	C40308			0.001	1				
CHRISTINA LK.	C48128	0.096	1			0.0893939	1		
CHRISTINA LK.	C52493			0.001	1				
CHRISTINA LK.	C58877	0.045	1						
CHRISTINA LK.	C59373			0.03	1				
CHRISTINA LK.	C62855			0.001	1				
CHRISTINA LK.	C62857			0.001	1				
CHRISTINA LK.	C66604	0.15	1						
CHRISTINA LK.	C70135			0.001	1				
COPPER CR.	C46150			0.001	1			0.1262626	1
COPPER CR.	F66253			0.002	1				
CORYELL CR.	F03275			0.001	1				
DYSON SPR.	C26701			0.001	1				
DYSON SPR.	C44357			0.001	1				
DYSON SPR.	C66416			0.001	1				
DYSON SPR.	C66417			0.001	1				
DYSON SPR.	F39726			0.001	1				
DYSON SPR.	F39728			0.001	1				
DYSON SPR.	F41114			0.001	1				
EARHART CR.	C53779			0.001	1				
EARHART CR.	C59416			0.001	1				
FERRARO SPR.	F39947			0.001	1				
GILL CR.	C23680			0.003	1				
GILL CR.	C25442			0.001	1				
GILL CR.	C41542			0.001	1				
GILL CR.	C45607			0.002	1				
GILL CR.	C66418			0.001	1				
GILL CR.	C66419			0.001	1				
HOFER CR.	C58081			0.001	1				
ITALY CR.	C42709			0.001	1				
LIGHTHOUSE CR.	F18168			0.001	1				
MAIDA CR.	F04583							0.1010101	1
MAIDA CR.	F39946			0.001	1				
MAIDA SPR.	C59374			0.002	1			0.0505050	1
MCRAE CR.	C33682			0.002	1				
MCRAE CR.	C33683			0.002	1				
MCRAE CR.	C64235			0.001	1			0.2525252	1
MCRAE CR.	?					0.005	1		
MURPHY SPR.	C39658			0.002	1				
PALMA SPR.	C59446			0.003	1				

PARSON CR.	C39990			0.001	1		
PARSON CR.	C47785			0.001	1		
RED OCHRE CR.	C43497			0.001	1		
ROBINSON SPR.	C44349			0.002	1		
SPOONER CR.	C49757			0.001	1		
SPOONER CR.	F15282			0.002	1		
SPOONER CR.	F19573			0.002	1		
STEPKINSON BR.	F17838			0.001	1		
STEPKINSON BR.	F17972			0.001	1		
STEPKINSON BR.	F19539			0.001	1		
STEPKINSON BR.	F19707			0.001	1		
STEPKINSON BR.	F61827			0.002	1		
STEWART CR.	C24431			0.001	1		
STEWART CR.	C24466			0.001	1		
STEWART CR.	C31939			0.001	1		
STEWART CR.	C32012			0.001	1		
STEWART CR.	C39900			0.001	1		
STEWART CR.	C43333			0.001	1		
STEWART CR.	C52996			0.001	1		
STEWART CR.	C60475			0.001	1		
STEWART CR.	C62151			0.001	1		
STEWART CR.	F18307			0.001	1		
STEWART CR.	F19120			0.001	1		
STEWART CR.	F67373			0.001	1		
STEWART CR.	F67374			0.001	1		
SUTHERLAND CR.	C45606	0.15	1				
SUTHERLAND CR.	C56462			0.001	1		
SUTHERLAND CR.	C57723			0.001	1		
SUTHERLAND CR.	C57724			0.001	1		
SUTHERLAND CR.	C58667			0.001	1		
SUTHERLAND CR.	C58668			0.001	1		
SUTHERLAND CR.	C58669					0.0151515	1
SUTHERLAND CR.	C58670			0.002	1		
SUTHERLAND CR.	C58671					0.0883838	1
SUTHERLAND CR.	C58672					0.0151515	1
SUTHERLAND CR.	C58673			0.001	1		
SUTHERLAND CR.	C59200			0.001	1	0.0883838	1
SUTHERLAND CR.	C59201					0.0631313	1
SUTHERLAND CR.	C59202					0.1578282	1
SUTHERLAND CR.	C60449			0.001	1	0.0378787	1
SUTHERLAND CR.	C60450			0.001	1	0.1515151	1
SUTHERLAND CR.	C60451			0.001	1	0.0378787	1
SUTHERLAND CR.	C60452			0.001	1		
SUTHERLAND CR.	C60453			0.001	1	0.1262626	1
SUTHERLAND CR.	C60454					0.0505050	1
SUTHERLAND CR.	C60456			0.001	1	0.0126262	1
SUTHERLAND CR.	C60457			0.001	1	0.0126262	1
SUTHERLAND CR.	C60473	0.45	1				
SUTHERLAND CR.	C62261			0.001	1		
SUTHERLAND CR.	C66372			0.001	1		
SUTHERLAND CR.	F17756			0.001	1		
SUTHERLAND CR. S. OUT.	C46151			0.004	1		
SUTHERLAND CR. S. OUT.	C46152			0.001	1		
SUTHERLAND CR. S. OUT.	C46153			0.001	1		

SUTHERLAND CR. S. OUT.	C49285	0.001	1				
SUTHERLAND CR. S. OUT.	C49384			0.001	1		
SUTHERLAND CR. S. OUT.	C49385	0.001	1				
SUTHERLAND CR. S. OUT.	F07828	0.001	1			0.0555555	1
SUTHERLAND CR. S. OUT.	F10388	0.0005	1			0.0770202	1
SUTHERLAND CR. S. OUT.	F10941	0.001	1				
SUTHERLAND CR. S. OUT.	F10942	0.001	1				
SUTHERLAND CR. S. OUT.	F11774	0.001	1				
SUTHERLAND CR. S. OUT.	F13331	0.001	1				
SUTHERLAND CR. S. OUT.	F13332	0.001	1				
SUTHERLAND CR. S. OUT.	F13333	0.001	1				
SUTHERLAND CR. S. OUT.	F13334	0.001	1				
SUTHERLAND CR. S. OUT.	F13335	0.001	1				
SUTHERLAND CR. S. OUT.	F13533	0.001	1				
SUTHERLAND CR. S. OUT.	F13534	0.001	1				
SUTHERLAND CR. S. OUT.	F13606	0.001	1				
SUTHERLAND CR. S. OUT.	F13607	0.001	1				
SUTHERLAND CR. S. OUT.	F16484	0.002	1				
SUTHERLAND CR. S. OUT.	F16535	0.001	1				
SUTHERLAND CR. S. OUT.	F16536	0.001	1				
SUTHERLAND CR. S. OUT.	F16537	0.001	1				
SUTHERLAND CR. S. OUT.	F16705	0.001	1				
SUTHERLAND CR. S. OUT.	F16706	0.001	1				
SUTHERLAND CR. S. OUT.	F16707	0.001	1				
SUTHERLAND CR. S. OUT.	F16708	0.001	1				
SUTHERLAND CR. S. OUT.	F17086	0.001	1				
SUTHERLAND CR. S. OUT.	F17087	0.001	1				
SUTHERLAND CR. S. OUT.	F17141	0.001	1				
SUTHERLAND CR. S. OUT.	F17167	0.001	1				
SUTHERLAND CR. S. OUT.	F17330	0.002	1				
SUTHERLAND CR. S. OUT.	F17331	0.001	1				
SUTHERLAND CR. S. OUT.	F19082	0.001	1				
SUTHERLAND CR. S. OUT.	F19325	0.001	1				
SUTHERLAND CR. S. OUT.	F19326	0.001	1				
SUTHERLAND CR. S. OUT.	F19328	0.002	1				
SUTHERLAND CR. S. OUT.	F19360	0.001	1				
SUTHERLAND CR. S. OUT.	F19579	0.001	1				
SUTHERLAND CR. S. OUT.	F19768	0.001	1				
SUTHERLAND CR. S. OUT.	F21108	0.001	1				
SUTHERLAND CR. S. OUT.	F21109	0.001	1				
SUTHERLAND CR. S. OUT.	F21110	0.001	1				
SUTHERLAND CR. S. OUT.	F21111	0.001	1				
SUTHERLAND CR. S. OUT.	F45779	0.001	1				
SUTHERLAND CR. S. OUT.	F45780	0.001	1				
SUTHERLAND CR. S. OUT.	F45781	0.001	1				
SUTHERLAND CR. S. OUT.	F46070	0.001	1				
SUTHERLAND CR. S. OUT.	F46485	0.001	1				
SUTHERLAND CR. S. OUT.	Q45778	0.001	1				
SWETLAND SPR.	C40567	0.002	1			0.2020202	1
SZIMMER SLOUGH	C24548					0.2121212	1
TEXAS CR.	F13311	0.002	1				
TEXAS CR.	F15276	0.002	1				
TEXAS CR.	F19080	0.002	1				
TREADMILL CR.	C29391	0.001	1				

WALKER CR.	C39901	0.001	1
WOODLEY CR.	C36605	0.001	1
WOODLEY CR.	C47157	0.001	1
WOODLEY CR.	C47455	0.001	1

APPENDIX C

EURASIAN WATERMILFOIL DATA

From: Retzer, B. and D. Haberstock. 1990. The 1989 Christian Lake Eurasian Watermilfoil Control Program. Littoral Resources Unit, Water Management Branch, Ministry of Environment, B.C.

Figure 1: Eurasian Watermilfoil (M. spicatum) Sites, Christina Lake, 1989

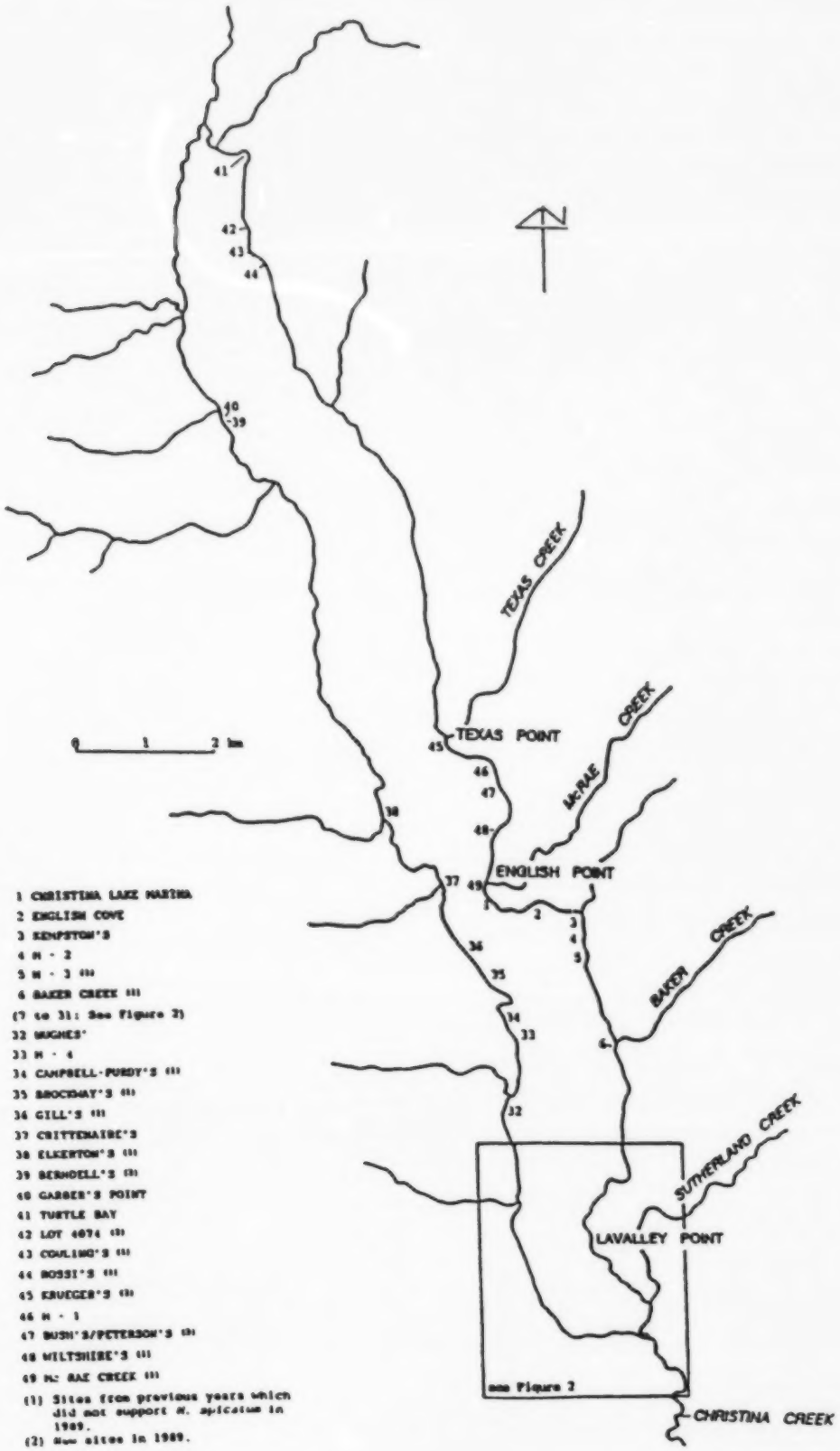
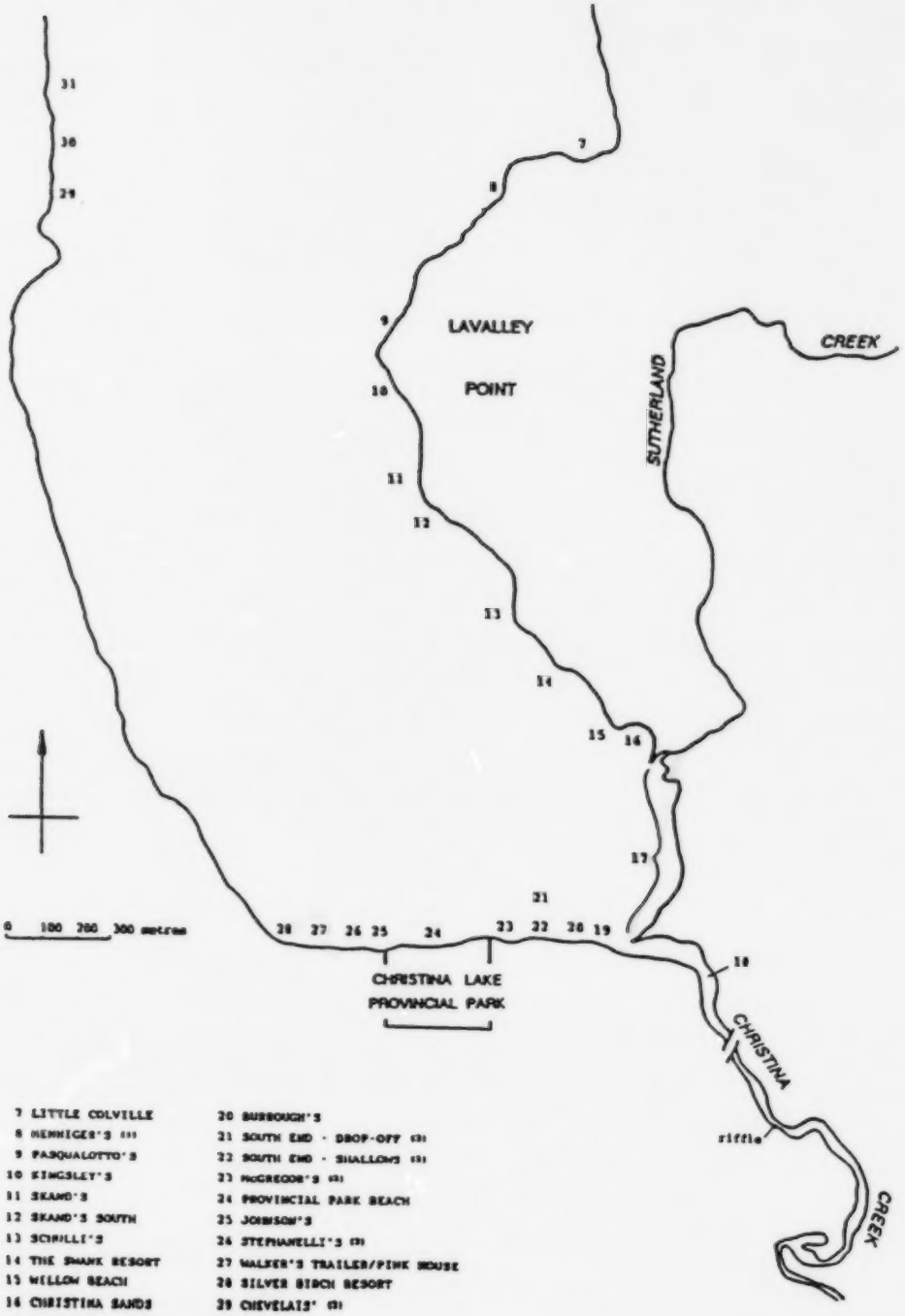


Figure 2: Eurasian Watermilfoil (M. spicatum) Sites,

South End of Christina Lake, 1989



7 LITTLE COLVILLE
8 HENNIGER'S (1)
9 PASQUALOTTO'S
10 KINGSLEY'S
11 SKAND'S
12 SKAND'S SOUTH
13 SCHILLI'S
14 THE SHANK RESORT
15 WILLOW BEACH
16 CHRISTINA SANDS
17 SUTHERLAND CREEK
18 CHRISTINA CREEK
19 BURNETT'S
20 BURROUGH'S
21 SOUTH END - DROP-OFF (2)
22 SOUTH END - SHALLOWS (2)
23 McGREGOR'S (2)
24 PROVINCIAL PARK BEACH
25 JOHNSON'S
26 STEPHANELLI'S (2)
27 WALKER'S TRAILER/PINK HOUSE
28 SILVER BIRCH RESORT
29 CHEVELAIS' (2)
30 LYONS' (2)
31 TRAVERY'S (2)

(1) Sites from previous years which did not support *M. spicatum* in 1989.
(2) New sites in 1989.

Table 1: HISTORICAL STATUS OF SITES SUPPORTING Myriophyllum spicatum, CHRISTINA LAKE

Site Name	1986	1987	1988	1989
1. CHRISTINA LAKE MARINA	14,000 stems(estimated) (1040 m2 Texel)	7 pl/213 stems (1700 m2 Texel laid to McRae Creek)	7 pl/14 st/1 frag (hr)	20 pl/52 st/2 frag (11 m2 geo. & 4 m2 discarded carpet)
2. ENGLISH COVE		1 pl/2 st (hr)	36 pl/131 st/34 frag (11 m2 Texel)	6 pl/14 st (2 m2 geo)
3. KEMPSTON'S		7 pl/501 st (600 m2 Texel)	1 pl/5 st (hr)	6 pl/14 st (hr)
4. M - 2			15 pl/62 st/2 frag (63 m2 Texel)	20 pl/41 st (44 m2 geo)
5. M - 3			13 pl/28 st/2 frag (17.5 m2 Texel)	no EWM
6. BAKER CREEK		4 pl/12 st (hr)	10 pl/24 st/23 frag (30 m2 Texel)	no EWM
7. LITTLE COLVILLE		24 pl/93 st (350 m2 Texel)	no EWM	11 pl/35 st (10.25 m2 geo)
8. HENNIGER'S			4 pl/9 st (28 m2 Texel)	no EWM
9. PASQUALOTTO'S			9 pl/22 st (9 m2 Texel)	6 pl/16 st (6 m2 geo)
10. KINGSLEY'S			11 pl/38 st/7 frag (21 m2 Texel)	10 pl/19 st/1 frag (3 m2 geo)
11. SKAND'S/YEAGER'S		33 pl/101 st/1 frag (270 m2 Texel)	27 pl/88 st/6 frag (360.5 m2 Texel)	72 pl/167 st (26.25 m2 geo)
12. SKAND'S SOUTH			17 pl/30 st/3 frag (hr)	14 pl/35 st (8 m2 geo)
13. SCHULLI'S			7 pl/21 st/13 frag (30 m2 Texel)	5 pl/13 st (2 m2 geo)
14. THE SWANK RESORT			16 pl/53 st (hr)	25 pl/43 st (9.25 m2 geo)
15. WILLOW BEACH			4 pl/14 st/1 frag (hr)	7 pl/16 st (1 m2 geo)
16. CHRISTINA SANDS			15 pl/42 st/6 frag (39 m2 Texel)	99 pl/328 st/4 frag (56.5 m2 geo)

Site Name	1986	1987	1988	1989
17. SUTHERLAND CREEK		1 pl/3 st (hr)	191 pl/642 st/35 frag (1675 m2 Texel)	571 pl/1794 st/24 frag (997 m2 geo)
18. CHRISTINA CREEK		72pl/369 st (hr)	211 pl/548 st/45 frag (427 m2 Texel)	275 pl/738 st/32 frag (228.5 m2 geo)
19. BURNETT'S			2 pl/4 st (hr)	7 pl/15 st (3 m2 geo)
20. BURROUGHS'			2 pl/7 st (hr)	14 pl/56 st (10.75 m2 geo)
21. SOUTH END - DROP-OFF				138 pl/320 st/12 frag (102 m2 geo)
22. SOUTH END - SHALLOWS				15 pl/53 st (30.75 m2 geo)
23. McGREGOR'S				7 pl/27 st (6 m2 geo)
24. PARK BEACH		14 pl/44 st (hr)	4 pl/8 st (2.25 m2 Texel)	3 pl/8 st (1 m2 geo)
25. JOHNSON'S		1 pl/12 st/3 frag (hr)	7 pl/20 st (24.5 m2 Texel)	8 pl/29 st (3 m2 geo)
26. STEPHANELLI'S				20 pl/74 st (12.25 m2 geo)
27. WALKER'S TRAILER/PINK HOUSE		24 pl/59 st/17 frag (hr)	4 pl/10 st (hr)	15 pl/53 st/5 frag (6.25 m2 geo)
28. SILVER BIRCH RESORT			1 pl/3 st (hr)	10 pl/28 st (3.25 m2 geo)
29. CHEVELAIS'				11 pl/28 st (14 m2 geo)
30. LYONS'				8 pl/13 st/9 frag (6 m2 geo)
31. TRAVERY'S				1 pl/2 st (4 m2 geo)
32. HUGHES'			8 pl/25 st/12 frag (21 m2 Texel)	6 pl/13 st (5 m2 geo)
33. M - 4			22 pl/60 st (hr)	2 pl/8 st (5 m2 geo)

Site Name	1986	1987	1988	1989
34. CAMPBELL - PURDY'S		10 pl/53 st (hr)	1 pl/3 st (hr)	no EWM
35. BROCKWAY'S		25 pl/35 st/14 frag (120 m2 Texel)	1 pl/1 st (hr)	no EWM
36. GILL'S			28 pl/99 st/18 frag (132 m2 Texel)	no EWM
37. CRITTENDAIRE'S		7 pl/14 st (hr)	4 pl/8 st/1 frag (6 m2 Texel)	1 pl/3 st (0.25 m2 geo)
38. ELVERTON'S		2 pl/14 st (hr)	no EWM	no EWM
39. BERNDELL'S				62 pl/174 st (62.25 m2 geo)
40. GARBER'S POINT		7 pl/18 st (hr)	31 pl/117 st/4 frag (110 m2 Texel)	15 pl/55 st (11.25 m2 geo)
41. TURTLE BAY			7 pl/32 st (31 m2 Texel)	3 pl/8 st (5 m2 geo)
42. LOT 4074				11 pl/68 st (15.25 m2 geo)
43. COULING'S		4 pl/14 st (hr)	no EWM	no EWM
44. ROSSI'S		24 pl/68 st (hr)	no EWM	no EWM
45. KRUEGER'S				34 pl/77 st (39 m2 geo)
46. N - 1			4 pl/16 st/3 frag (17 m2 Texel)	4 pl/10 st (2 m2 geo)
47. BUSH'S/PETERSON'S				7 pl/19 st (7 m2 geo)
48. WILTSHIRE'S	29 pl/35 st (92 m2 burlap)	1 pl/2 st (hr)	no EWM	no EWM
49. McRAE CREEK		see Christina Lk. Marina 1987	no EWM	no EWM
TOTALS:	approx. 14,035 stems (1040 m2 Texel & 92 m2 burlap)	<968 pl/1627 st/35 frag (3040 m2 Texel)	720 pl/2184 st/216 frag (3054.75 m2 Texel)	1549 pl/4464 st/89 frag (1759 m2 geo & 4 m2 carpet)

NOTES pl = plants; st = stems; frag = fragments; (x m2) = square metres of bottom barrier installed; hr = hand removed; geo = geotextile material; EWM = Eurasian watermilfoil (M spicatum)